TREATMENT OF STOCK YARD'S SEWAGE
BY THE
ACTIVATED SLUDGE PROCESS

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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THE TREATMENT OF STOCK YARD'S SEWAGE BY THE ACTIVATED SLUDGE PROCESS

A THESIS

PRESENTED BY

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TO THE

PRESIDENT AND FACULTY

OF

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PLANT.

The activated sludge plant originally consisted of a rotary screen, four tanks in which the sewage is aerated, one tank for settling the aerated sewage, one sludge storage tank, two blowers with motors for supplying air, a sludge pump for returning the sludge to the aeration tanks from the settling tank, or sludge storage tank, and a venturi meter with recording apparatus.(Fig.1).

The rotary screen is of the Weand type, cylindrical in shape, 2 ft. 4 in. diameter by 4 ft. 8 in. long, covered with 30 mesh brass wire screen supported on 1/2 in. mesh screen. Jets of water automatically play on the outside for cleaning purposes. The screenings are carried along by a worm inside the cylinder and drop by gravity into an ash can at the end.

The four aeration tanks (tanks 3,4,5 and 6) are each 6x23 ft. in plan, 12 ft. deep, inside dimensions, with air distribution of Filtros plates set in hopper bottoms. The capacity of each tank is about 11,000 gallons to the flow line. The tanks are connected in series, and provided with inlet and drain pipes so that they can be operated separately on the fill-and-draw plan, as well as a whole with a continuous flow. The air system is arranged with a main header to each tank, from which branch pipes feed to each set of plates. Two small Venturi Meters (3" tube and 1 1/2" throat) were provided to set on the main header line in a by pass to check up the flow of air to each tank.

Settling tank 7 (fig.4) is 12 ft. in diameter with 12 ft. staves, built with a hopper bottom of the Dortmund Type, with a slope of 0.6 vertical to one horizontal. The sewage enters the tank in the center near the bottom, the settled sewage passing off from the top around a peripheral weir. The tank is provided with a sludge pipe for discharging sludge onto the drying beds, and a suction pipe to the sludge pump.

The Old Dortmund tank (tank c.fig.4) has been fitted up as a sludge storage tank. It can also be used as a Settling tank in connection with one of the aeration tanks.

Two rotary blowers of the Connersville make, Boston type, supply the air for the plant, one with a capacity of 300 cu. ft. per minute against a pressure of 6 lb. per square inch, driven by a 20 H.P. motor, the other with a capacity of 150 cu. ft. per minute against a pressure of 10 lb. per sq. in. driven by a 10 H.P. Motor.

The plant was operated with above equipment from Jan. to Oct. 1916. During this period several minor changes were made, as will be noted later in the report. On Oct. 19, 1916, Settling tank 7 was abandoned and the old Dortmund tank (tank D) was remodeled and used as a Settling tank. Two sludge concentration tanks, and a horizontal flow Settling tank were added to the equipment.

The old Dortmund (tank D-Fig.5) which was fitted up as a

Settling tank is 10 ft. in diameter with 16 foot Staves built with a hopper bottom with a slope of 1.8 vertical to one horizontal. The sewage enters the tank in the center 7 ft. 9 in. from top of tank, the settled sewage passing off from the top around a peripheral trough which has a sloping bottom. The tank is provided with a sludge pipe which can be used bothfor discharging sludge onto the drying beds, and feeding sludge to the sludge circulating pumps. The Tank was also fitted with a sludge air lift.

The two sludge concentration tanks (tanks A & B) are each 2 ft. in diameter by 20 ft. and 10 ft. deep, respectively. They are made of galvanized iron and are fitted with pipes for filling and emptying thru the bottom, with outlet pipes so fitted as to discharge onto the sludge beds.

The horizontal settling tank (tank 8-fig.6) is 5 x 15 ft. in plan by 10 ft. deep, inside dimensions. The sewage entering thru a distributor 5 ft. from top of tank, while the settled sewage passes off from the top thru a moveable Effluent trough. The sludge settles into three (3) hoppers at the bottom of the tank, each of which have a slope of 2 vertical to 1 horizontal. Each hopper is provided with a sludge pipe discharging into the main sludge line which is connected to the pump and sludge beds, as well as a sludge air lift.

OPERATING DATA PRIOR TO JULY 1, 1916.

The dates on which the tanks went into service are given in the following table:-

Tank No.	DATE - 1916.	Method of Operation.
3	Jan. 10	Fill and Draw
4	Jan. 15	Fill and Draw
5	Jan. 20	Fill and Draw
6	Jan. 25	Fill and Draw

The tanks were first operated to accumulate sludge. From Feb. 24 to March 8, tanks 3 and 4 were operated on the continuous flow plan, with tank 7 as a Settling tank. From March 8 to April 18 all of the tanks were operated on the continuous flow plan. The results were not satisfactory, owing to the poor condition of the air distribution system. Considerable septic sludge was found in the air ducts at the bottom of the tank. The averages for the period April 1 to 15 inclusive, show a use of air at the rate of 0.37 cu. ft. per minute per sq. ft. or 10.6 cu. ft. per gallon of sewage, actual flow, with periods of 25.6 hrs. in the aeration tanks and 3.4 hrs. in the settling tanks respectively. During the period April 20 to May 19, the tanks were operated on the Fill and Draw plan, while the air distribution system was being rebuilt.

From May 19 to June 1, the entire plant was operated on a continuous flow basis but the results were not satisfactory, apparently because the sludge on hand had been over aerated in the period of sludge storage during repairs. On June 1, the continuous flow was abandoned, the plant being operated from June 1 to July 1 on the Fill and Draw Plan to accumulate fresh sludge. During this period, also, the perforated air pipes were removed from tanks 5 and 6 and

the Filtros plates refitted. From July 2, 1916 to March 27, 1917, the plant has been operated on the continuous flow basis, with the sewage and sludge being aerated the same period.

AIR MEASUREMENTS.

At the start the recording device on the 5 inch Venturi air meter did not agree with the Manometer directly connected at the meter tube. The manometer readings were, therefore recorded hourly. The temperature of the air was taken every 2 hours at the entrance to the meter, while the pressure was taken with a mercury manometer at the meter. The air calculations are computed from the manometer readings, reduced to cubic feet of free air at atmospheric pressure, and 62° Fahr, temperatures.

To reduce the pulsating effect of the blowers, a cylindrical steel storage tank, 4 ft. diameter by 4 ft. high was set in the air line between the blowers and the Venturi Meter. This made the readings of the manmoeter and recorder in substantial agreement.

FILTROS PLATES.

The four aeration tanks were Each fitted with 22 filtros plates (12" x 12" x 1 1/2"), which made the ratio of plate to tank area 1 to 8. The plates were arranged differently in Each pair of tanks (Fig. 2 and 3). In Tanks 5 and 6 the plates were set in one row down the center, while in tanks 3 and 4 the plates were set in rows transverse to the length of the tank. The plates were set in wooden boxes lined with galvanized iron, with bearing surface in boxes only along their length. The spaces between plates were filled with melted Jointite and wooden strips were placed over edges of plates along lengths of boxes, to hold the plates down. The boxes which contained 3 or 4 plates were supplied with Air by means of a 1 1/2" pipe leading from a main air header, over Each tank. With this arrangement the air supply to Each box could be regulated, which was essential as the plates vary in porosity. Plates of the same porosity were placed in the same box (Fig. 2 and 3).

During the period April 20 to May 19, the tanks were operated on the fill and draw plan, while the filtros plates were examined. Examination showed cracked filtros plates in all the tanks. In Tanks 5 and 6, practically every plate was broken longitudinally at the center, in a single row down the middle of the tank. This was apparently due to insufficient bearing surface or poor bedding under the plates. In tanks 3 and 4 the filtros plates were in better condition, though many were cracked. However, these tanks were equipped with new boxes lined with galvanized iron, in which each plate was supported on all four sides. Tanks 3 and 4 were refitted with the used plates which were in good condition, the deficit being made up with new plates. The plates were first bedded in Portland cement, the spaces filled with Jointite and the plates were fastened down ~~the spaces~~ with band iron strips. Tanks 5 and 6 were fitted with perforated iron air pipes and a system of baffles. During the latter part of June, 1916, the air pipes were replaced with filtros plates.

A satisfactory method for cleaning the surface of the plates is

wanted. As the plates gradually become clogged grit and screenings accumulate on the surface. Two methods of cleaning the surface have been tried with little success, namely a wire brush at the end of a long pipe, and a suction pump (similar to air lift) applied to surface of plates.

During the period March 6 - 26, the Filtros Plates in all the tanks were examined. The result of the inspection brought out these facts:

1. Five plates were either cracked or broken in tanks 5 and 6, while all the plates in tanks 3 and 4 were in good condition, thus there was a total loss of 5 plates out of 88 plates or 5.7% during 8 months of operation.

2. A clogging of the under surface of the plates due to dust from air which passed thru the 40 mesh screen on the suction chamber of blowers, was noted on plates removed. This can be remedied by washing the air.

3. The plates can be readily removed without breaking when set in place as follows: The plates were first bedded in cement and the spaces between plates filled with Jointite. The boxes holding plates should be made large enough so that there will be a distance between plates of 1/4" to 3/8" to allow room to pour the melted Jointite. The plates can be removed by melting the Pitch or Jointite.

4. Filtros Plates should be examined at least once a year and the surface scrubbed with a wire brush.

5. The available plate area was reduced from 22 sq. ft. to 16.4 sq. ft. on account of the band iron strips used to fasten down the plates. This reduced the ratio of plate area to tank area from $\frac{1}{6.3}$ to $\frac{1}{8.4}$.

The following table shows the gradual increase in air pressure due to the clogging of filtros plates. The net increase in 8 months is equivalent to 3 ft. water or 1.32 lbs. per sq. inch. As a result of this increase in air pressure, the capacity of the blowers decreased.

PERIOD.	AIR PRESSURE FT. H-2-O
July 1 to July 31, 1916	12.9
Aug. 1 to Aug. 31, 1916	12.6
Sept 1 to Sept 16, 1916	13.3
Sept 17 to Oct. 14, 1916	13.7
Oct. 15 to Oct. 22, 1916	14.3
Oct. 23 to Nov. 23, 1916	15.5
Nov. 24 1916 to Jan. 7, 1917	15.0
Jan. 8 to Feb. 4, 1917	15.6
Feb. 5 to Mar. 5, 1917	15.6

Washing the air and screening the sewage will aid considerably

in preventing this increase in air pressure.

Specimens of filtros plates removed showed a marked penetration of dust into plates from under surface, which was burned on igniting plates with a very slight loss in weight.

SAMPLING DATA.

Samples were taken regularly for chemical analyses every hour. On working days these were made up into composites, for the day flow from 7 A.M. to 9 P.M. and for the night flow from 9 P.M. to 7 A.M. On Sundays and holidays, a composite sample was made up for 24 hours.

Composite samples were made of the day screened sewage, the night sewage and the Effluent of the settling tank, both for day and night flows. Hourly samples were taken of the settling tank effluent to determine the relative stability by the methylene blue method. Beginning with Aug. 27, 1916, samples for relative stability were taken from the outlets of aeration tanks #4 and #5.

Begining with Oct. 30, 1916, samples were taken every 2 hours of the effluent of the settling tank for the Biologic Oxygen consumed test by the saltpeter method. These samples were composited into day and night periods. Begining with Nov. 24, 1916, samples were taken every 6 hours of the effluent of the settling tank for the Dissolved Oxygen content.

Samples of the screenings were taken daily for moisture content, and weekly composite for complete analyses. Samples of the activated sludge were taken weekly from the outlet end of final aeration tank (tank 6), for complete analyses. All sludge disposed of was sampled for the moisture content.

Settling tests of the sludge in all tanks were made every 4 hrs. These tests were carried out in 100 c.c. graduated cylinders, and 1/2 hour as well as 1 hour readings recorded.

OPERATING DATA.
JULY 1, 1916 TO MARCH 26, 1917.

During the interval July 1, 1916 to March 26, 1917, inclusive, the results have been divided into 15 separate runs, according to the rate of flow of sewage and the settling period as noted in the following table #1. During the entire period the day sewage was passed thru a 30 mesh rotary screen except on Sundays and holidays and during run #7 (Sept. 17, 1916 to Oct. 15, 1916).

T A B L E 1.

As shown in the Report on Industrial Waste from the Stockyards and Packingtown on working days, the day sewage is much stronger than the night flow. The operation of the plant was not varied during the 24 hours, except to shut down the screen from 9 P.M. to 7 A.M., and to shut off the sewage whenever it was necessary to dispose of the excess or accumulated sludge which was about once per day. This interruption in the operation would be avoided in a large plant as there would be sufficient surplus sludge so that it could be pumped continuously to sludge storage tanks for further treatment. On Sundays and holidays the sewage approximated the night flow. The screen was then shut down and the amount of air applied was frequently reduced.

The air control was governed chiefly by the physical properties of the sludge (i.e. its color, settling qualities and general appearance), and dissolved Oxygen and relative stability of the effluent.

The sludge was returned continuously from the settling tank to the inlet of tank #3, by either a 1 1/2 inch or 2 inch centrifugal pump, or a 2 1/2" air lift. The amount returned varied with the rate of flow of the sewage and the settling qualities of the sludge.

OPERATING STANDARDS.

Operation started with a definite flow period, which was varied so as to obtain different aeration and settling periods. The rate of flow of sewage was kept constant thru out each run. The air was varied so as to obtain a clear and fairly stable effluent. During the cold weather the plant was operated for the greater part of the time for the purpose of obtaining the minimum air consumption for different aeration periods, so as to obtain a clarified effluent only, disregarding the relative stability. Besides the nature of the effluent, other criteria are evidently important especially the condition of the sludge, particularly in determining the quantity of air required and the amount of sludge to be returned to the aerating tanks. In warm weather samples from the different aerating tanks indicated that the sewage above the sludge was speedily clarified, sometimes being clear in tank 4, and usually as clear in tank 5 as in tank 6, while the settling qualities of the sludge in the different tanks increased from tank 3 to tank 6, in proportion to the amount of air. During the colder weather, stable samples have not been obtained for a period of sufficient length to draw compareable conclusions. When operating for clarifaction only in the cold weather

the settling qualities of the sludge in the different tanks decreased from tank 3 to tank 6.

CONTINUOUS OPERATION.

The plant was operated continuously on a continuous flow basis without serious interruptions from July 1, 1916 to March 26, 1917. Frequently, however, the flow of sewage and sludge was interrupted for short periods, while sludge was wasted or the settling tank cleaned. During the winter with the temperature very often below zero degrees Fahr., very little trouble was experienced from freezing, however, caution was taken to drain all pipes when stopping the flow of Sewage for any length of time.

On several occassions the state of activation of the sludge decreased, at which time it was necessary to aerate the tanks and shut off the flow of sewage. The additional aeration of the tanks for several hours usually brought the sludge back to its original or fully activated state. During these intervals considerable foam was formed on the surface of the tanks, which also takes place during the period when activated sludge is first formed.

SLUDGE.

From the operating standpoint, the sludge has certain characteristics which vary according to the weather conditions. Up to a certain point the settling quality of the sludge improved with an increase of air. If the amount of air is excessive, the sludge will settle very fast and then rise. The volume also will decrease. A marked improvement in the settling was often observed from Sunday morning to afternoon, with the rate of air the same, but with a sewage becoming weaker.

In warm weather the rate of settling of the sludge was much faster in tank #6 than in tank #3, while in winter the opposite is the case but not to such a marked degree. Very often the slow settling of the sludge caused a rapid filling of the settling tank, which necessitated special pumping or wasting of the sludge.

AIR.

The only preliminary treatment given the air was allowing it to pass thru a 40 mesh brass screen. The application of the air was generally at a much lower rate on Sundays and holidays except when the sludge settled very slowly. Excess aeration was then resorted to. During the winter the air was generally allowed to remain the same on Sunday, so as to condition the sludge properly.

AERATION TANKS.

RUN #1 - JULY 2,-11, - 1916.

During this period the sludge increased rapidly owing to the slow settling qualities, induced by insufficient aeration. On July 7, the sewage flow was cut off. Continued aeration restored the sludge to its normal condition.

RUN #2 - JULY 11-15, 1916.

On the night of July 12, the belt on the large blower broke. With

only the small blower operating, the air was reduced from 175 to 130 cu. ft. per minute. The samples were inferior to the average, especially the relative stabilities.

RUN #3 & 4 - July 15 - Aug. 15, 1916.

During this period the air supply was changed more often, particularly on Sundays. This was governed largely by physical observations of the sludge and effluent, as well as the relative stability. The operation during run #4 was the same as #3, except that a shorter inlet pipe was placed in the settling tank, thus decreasing the settling volume as well as the settling period. The results are exceedingly valuable.

RUN #5 - Aug. 15 - 29,1916.

With the increase flow, numerous test samples of sludge taken from tanks 3 and 4 became septic in from 1 to 2 hours. Despite the increased flow excellent results were obtained with a lower air consumption per gallon of sewage, altho higher per square foot of tank area. The distribution was much better. The rate of application of air was changed as in preceeding runs, according to the nature of the sludge and effluent.

RUN #6 - Aug. 29 to Sept. 16,1916.

Altho the rate of sewage was reduced to 72,7500 gallons per day, the total flow through the plant was the same as in the preceeding period, the difference being offset by the increase in amount of sludge returned. At times the sewage flow was cut off, and the sludge pump worked at maximum capacity to return the sludge to tank 3. Again tank 7 was cut off, the sludge settled and in part drawn off to sludge drying beds or wasted.

RUN #7 - Sept.17 Oct.14,1916.

Operation was the same as in run #6 except that the screen was not operated, so as to note effect of screen. The results during this period were slightly inferior to those obtained during the previous run, however the air temperature dropped 10 degrees which must be taken into consideration. At start of run, the sludge became lighter in color, settled slower and was less floculent in appearance. The air was increased and on Sept. 21, the sludge became normal again. There was an accumulation of screenings on the tie rods at the top of tanks 3 and 4, and screenings were also noted in sludge orifice box.

The sludge pumps were examined at the end of the run, and considerable hair and fibrous material was found around shaft between face and propellor and also around discharge pipe.

RUN #8 - Oct. 15 - 23, 1916.

The screen was again put in operation. On Oct. 19, settling tank 7 was replaced by settling tank D, which had been remodeled from the old Dortmund tank. During this run, tank 5 was partly drained so that the pipe between tanks 4 and 5 could be examined, as there was

a loss of head of 4 1/2 inches between tank 4 and 5. Examination showed an accumulation of screenings around a piece of rubber gasket which had not been placed in properly between flanges in the middle of the pipe. This was remedied and was the cause of the excessive loss of head. The air consumption per gallon of sewage was lower than any other run to date, and the results obtained were good.

RUN #9 Oct. 23 - Nov. 24, 1916.

The rate of sewage was increased, and was higher than any other run, which gave theoretical aeration and settling periods of 7.2 and 0.65 hours respectively. Clarification but not stability was obtained during this run. Several times it was necessary to increase the air, as the sludge would not settle fast enough. The physical properties of the sludge gradually changed and the following observations were made on Nov. 21. The sludge was of the typical chocolate brown color, floculent and did not settle as fast as usual. Tank 3 sludge settled the fastest and rate of settling decreased in other tanks, tank 6 settling the slowest. The supernatant sewage in all tanks was turbid except that in tank 6 which was fairly clear. These are the characteristics of the sludge in cold weather, when operating for clarification only.

During this run too much sludge was returned to aeration tanks, and not enough wasted, which accounts for the low sludge yield. The chemical results are much inferior to those obtained in previous runs.

RUN #10 - Nov.24 - Dec. 8, 1916.

The rate of flow of sewage was decreased. The % of sludge at start of run was high, so the amount of sludge returned to the aeration tanks was decreased, and excess sludge was wasted. This accounts for the high sludge yield. On Dec. 6, the sludge settled very slowly, so the 2 blowers were used part of the day. On Dec.7, the tanks were aerated with the sewage shut off. This proceedure brought the sludge back to its normal state, and accounts for the high air consumption during the run. Clarification was obtained but the relative stabilities were very low.

RUN #11 - Dec. 8 to Dec. 16,1916.

During this run an attempt was made to obtain a stable effluent with the same rate of flow of sewage or the same aeration and settling periods. Both blowers were operated continuously. At the start of the test the sludge was not fully activated and settled very slow. The sludge soon became fully activated with the characteristic physical appearance and properties. Altho the air consumption was 6.52 cu. ft. per gallon sewage, it was not sufficient to give an effluent that was absolutely stable. The slight improvement in character of effluent with the decided increase in air consumption did not warrant further experimentation in this direction.

RUN #12 - Dec. 16 - Jan.7, 1917.

The rate of flow of sewage was not changed, altho the amount treated was larger, and aeration and settling periods lower, as there

were less interruptions in the operation. The air was materially decreased and the plant was operated so as to obtain a clarified effluent with a minimum air consumption. The relative stabilities were very low during this test. At the start of the run, the sludge began to show signs of being over activated. The sludge was of a light straw color, settled very fast leaving considerable floculent material in suspension which settled very slowly. The air was reduced, and the sludge soon exhibited its normal properties. On Dec. 23rd, the plant was completely shut down for about 3 hours during the morning on account of trouble with the electric power. On Dec. 25th, the sludge again became over activated, on account of the very weak sewage on 2 successive days, altho the air was decreased. Some small particles of screenings which probably entered tanks while screen was not operating, would settle out in sludge orifice box, as well as in box feeding settling tanks.

The horizontal flow settling tank #8 was operated during part of the run, but it soon had to be abandoned on account of the rate of flow of sewage being too large for its capacity.

RUN #13 - Jan. 8 - Feb. 4, 1917.

During this run, the rate of flow of sewage was decreased, so as to increase the aeration and settling periods. This was done so that an effluent of a higher relative stability value could be obtained. Both settling tanks 8 and D were operated at different times during this run. Tank 8 gave satisfactory results, except when sludge settled slowly. On account of the slow settling of the sludge, the % in the aeration tanks became low, which necessitated increasing the rate of sludge returned. During this run, the air was varied considerably on account of the rapid changes in the physical properties of the sludge, the settling properties being chiefly effected.

With the increase in the aeration period an increase in the relative stability was noted as well as a much better effluent.

RUN #14 - Feb. 5 - Mar. 5, 1916.

The rate of flow was again increased so as to obtain an aeration period of about 8 hours. With this period, the air was regulated so that clarification could be obtained disregarding the relative stability of the effluent. The purpose was to obtain minimum air consumption figures for clarification during the month of Feb. The screen was not operated for 7 working days during this test, while waiting for necessary repairs.

Very little trouble was experienced with the sludge during this run, as it exhibited very rapid settling properties in all the aeration tanks. The effluent was fairly clear most of the time, while the air consumption was the lowest of all the runs being 3.17 cu. ft. per gallon of sewage treated.

RUN #15 - March 6 - March 26, 1916.

During this period while the tanks were being overhauled and necessary changes made for the separate sludge aeration --

~~aeration~~ method of operation, tanks 3 and 4 were operated only, and were directly connected to the settling tanks. Both settling tanks D and 8 were in use at different intervals during this run. Results were similar to those obtained in the previous run, altho the aeration period was much lower, being 6.9 hours. The air consumption was increased to 4.23 cu. ft. per gallon of sewage treated, which resulted in an improvement in the character of the effluent.

A summary of the operating results for the different periods are given in tables 2 and 3.

SETTLING TANKS.

TANK 7

The hopper of the settling tank (tank 7) was built with side slopes of 30 degrees with the horizontal. This proved too flat. During the period July 2 to 11, considerable difficulty was experienced in the septicization of the sludge in the settling tank, due not only to adherence to the hopper slopes, but also to the under surface of the outlet trough. Careful cleaning with a galvanized iron scraper pushed up and down proved fairly satisfactory, if executed several times a day. The result of such scraping was clearly noticed in the color of the sludge returned to the plant directly after the scraping.

The difficulty with septicization was found to continue thru the period of July 11 to 15. On July 27 the settling capacity of the settling tank was reduced from 5840 to 3570 gallons by shortening the inlet pipe. The difficulty with septicization of the sewage in the hopper bottom persisted, so that frequent cleanings were required.

With the increased flow from Aug. 15 to 29, the same difficulty was noted. The settling capacity of tank 7 was increased on Aug. 17, from 3570 to 5070 gallons by lengthening the inlet pipe.

During the period August 29, to Sept. 16, slow settling sludge was noted. This gave less trouble with adhering to the bottom of the tank, flowing more readily with the high moisture content of 99 per cent and over.

Considerable trouble was again experienced with sludge during run #7, which necessitated its cleaning on Sept. 26th. However, during this period, there were intervals when the sludge was not completely activated which was noted by its slow settling properties. Sludge in this condition has a higher moisture content and flows more readily.

TANK D.

On Oct. 19, 1916, settling tank D which has been previously described, was placed in operation in place of Tank 7. This tank has given excellent results at all times, no trouble being experienced in the septicization of the sludge. The slope of 45 degrees on the bottom of the effluent trough, and the slope of 1.8 vertical

horizontal of the hopper bottom, proved sufficient to prevent

Date 1916	
July	
July	
(incl	
July	
July	
(incl	
July	
July	
(incl	
July	
Aug.	
(incl	
Aug.	
Aug.	
(incl	
Aug.	
Sept.	
(incl	

while the actual horizontal velocity was 26 ft. per hour.

GENERAL.

Definite conclusions cannot be drawn from the horizontal flow type of tank based on experiments with a tank with a horizontal distance of travel of only 15 feet. With the tanks experimented upon, the % of the settling volume which is effective, is much lower

THE SANITARY DISTRICT OF CHICAGO
AVERAGE RESULTS OF ACTIVATED SLUDGE EXPERIMENTS
JULY 2 TO SEPTEMBER 16, 1916.

Date 1916	Hrs. Operated			Rate			Average Flow	Daily Gallons			Period of flow Hours		Settling Period Hours		Air			Rate of Flows	Sludge Aver. Percent Air Tank 6 Settled 1 hr.
	Sewage	Sludge	Air	Sewage G.P.D.	Sludge Gal.Min.	Air c.f.m.	Sewage	Sludge	Wash Water*	Total	Apparent	Actual	Apparent	Actual	Cu.Ft.per 24 hrs.	c.f.m. per sq. ft.	cu.ft.per gal. sewage	Sludge / Sewage	
July 2 to July 10 (incl.)	21.2	21.1	24.0	57,500	31	138	50,900	38,800	3,830	92,300	18.5	10.2	2.4	1.4	198,900	0.25	3.91	0.76	29
July 11 to July 14 (incl.)	23.5	22.4	24.0	52,000	19	155	50,500	25,400	4,500	80,400	20.9	13.2	2.8	1.7	222,500	0.28	4.41	0.50	19
July 15 to July 26 (incl.)	23.7	23.4	24.0	53,500	18	155	52,960	25,500	4,020	81,840	19.9	13.0	2.6	1.7	223,500	0.28	4.22	0.48	31
July 27 to Aug. 14 (incl.)	23.7	23.7	24.0	53,600	18	145	53,300	25,500	2,870	81,730	19.9	12.3	1.6	1.04	208,900	0.26	3.95	0.48	34
Aug. 15 to Aug. 28 (incl.)	23.2	23.0	24.0	79,500	27	186	76,800	36,900	5,600	118,500	13.8	9.0	1.5	1.0	267,600	0.34	3.50	0.48	24
Aug. 29 to Sept. 16 (incl.)	22.2	22.4	24.0	72,750	35	173	67,600	47,2[illegible]	5,740	119,600	15.7	8.8	1.8	1.0	249,700	0.31	3.72	0.70	46

Notes:

Day considered 8 A.M. to 8 A.M.
Rate of sewage based on constant head orifice box.
Rate of sludge based on ½ hour readings of orifice box.
Period of flow based on (Apparent:-Actual flow of sewage and flow capacity of tanks.
(Actual :-Total flow and flow capacity of tanks.
Settling period basedon (Apparent:-Actual flow of sewage and settling capacity of tank.
(Actual :-Total flow and settling capacity of tank.

*Wash water average for days used only.

Air Readings:-
Calculated as cu. ft. free air at 30" mercury pressure and 62° F. temp. Correction has been made for variation in pressure and temp.

THE SANITARY DISTRICT OF CHICAGO

ENGINEERING DEPARTMENT

Activated Sludge Experiments Operated on Results Computed by J. J. N. Corbett

Computed by J. J. N. Corbett

Date	Hours Operated			Rate			Average Daily Flow Gallons				Period of Flow Aeration Hours			Settling Hours		Air				Rate of Flow Sludge / Sewage	Sludge Average % in Tank 6 Settled 1 Hr.
	Sewage	Sludge	Air	Sewage G.P.D.	Sludge Gal. Min.	Air c.f.m.	Sewage	Sludge	Wash® Water	Total	Diluted	Sludge	Aeration	Actual		cu. Ft. per 24 Hours	c.f.m. per sq. ft.	cu. ft. per Gallon Sewage		
Sept. 17 to Oct. 15	22.2	21.8	24.0	72750	35.4	1.71	67500	46500		114000	1.57	9.3	1.8	1.06		247000	0.31	3.66		0.69	45
Oct. 15 to Oct. 23	22.7	21.8	24.0	72750	34.2	1.57	63700	45000	6300	114400	1.54	9.9	1.8	0.95		225000	0.28	3.27		0.65	33
Oct. 23 to Nov. 24	21.0	21.2	24.0	37000	45.0	2.45	85000	57000	4760	146700	1.25	7.2		0.65		354000	0.44	4.17		0.67	30
Nov. 24 to Dec. 8	20.1	19.7	24.0	80250	27.8	2.64	67300	33000	4250	104400	1.46	9.4		0.85		300000	0.48	5.63		0.49	54
Dec. 8 to Dec. 16	21.2	21.4	23.8	80250	29.8	3.25	70840	33400	5030	113600	1.42	8.3	1.8	0.84		462600	0.59	6.52		0.54	25
Dec. 16, 1916 to Jan. 9, 1917	21.7	22.2	23.8	80250	35.7	2.08	72600	47700	4600	124000	1.56	8.5	1.8	0.77		296000	0.38	4.07		0.66	19
Jan. 8 to Feb. 5	20.4	21.2	24.0	55000	34.8	1.31	47700	44200	5600	96500	2.21	10.9	2.0	0.93		189000	0.24	3.97		0.93	28
Feb. 5 to Mar. 6	20.4	21.3	24.0	81600	43.5	1.56	70700	55500	7400	130900	1.49	8.7	1.54	0.73		224000	0.28	3.17		0.79	20

THE SANITARY DISTRICT OF CHICAGO ENGINEERING DEPARTMENT

Computed by J. J. N. Corbett

to 1 horizontal of the hopper bottom, proved sufficient to prevent the sludge from adhering to either. In this tank, the sewage has a vertical flow of 6 ft. 9" and a horizontal flow of 4 ft. to the effluent trough which is notched so that there will be a uniform flow thru the tank.

The theoretical settling period noted in tables has been calculated from the total flow (sewage and sludge) into the tank and the volume of the settling compartment (volume between inlet and outlet). The volume of sludge which is being removed continuously from the settling tank was not taken into consideration. The theoretical detention period in this tank has varied from 0.65 to 1.06 hrs. which is equivalent to vertical velocities of 10.4 to 6.4 ft. per hr.

On Feb. 15 and 26, 1916, flow tests were made on Tank D to determine the actual detention or settling period. Ten pounds of soda ash were used in each test, and samples of the inlet and outlet were taken at regular intervals and the alkalinity determined. The results were plotted (Fig. 7 & 8). The actual settling period from these tests was about 1 hour, while the theoretical period was only 40 minutes. The difference being due to the sludge removed continuously, which was not taken into consideration. The actual maximum vertical velosity would thus be reduced to 6.75 ft. per hour.

TANK 8.

During the early part of Jan. 1917, the horizontal flow settling tank (tank 8, fig. 6) was placed in operation. Considerable trouble was experienced with proper distribution and agitation at the inlet end of tank. This was remedied by building a baffle the width of the tank, 8" from end of tank and 4' 8" deep. The sewage enters the tank 4' 6" below surface and passes into tank thru a distributor containing 7 holes, 2 1/2" diam. each, which are placed along the entire width of tank between the baffle and end of tank.

Several tests with this tank were made during January, and the results obtained were satisfactory only when the sludge exhibited fast settling properties. The rate of flow of sewage was too high for the size of the tank.

With a decrease flow of sewage from March 6 to 26, very good results were obtained with tank 8 with a theoretical settling period of 0.9 hour.

On Jan. 10, 1917, a flow test was made on tank 8, similar to the tests made on tank D; however only 5 pounds of soda ash were used. The results were plotted (Fig.9.) The actual settling period from this test was about 35 minutes while the theoretical period was 44 minutes. The theoretical horizontal velocity was 20 ft. per hour, while the actual horizontal velocity was 26 ft. per hour.

GENERAL.

Definite conclusions cannot be drawn from the horizontal flow type of tank based on experiments with a tank with a horizontal distance of travel of only 15 feet. With the tanks experimented upon, the % of the settling volume which is effective, is much lower

with the horizontal flow than the vertical flow tank. This is clearly brought out on comparing the actual flow periods with the theoretical periods which were as follows:

TANK	SETTLING PERIODS. Theoretical		
	On sewage and Sludge	On Effluent	Actual from flow test.
Horizontal Flow Tank 8	44 Minutes	1 Hr. 13 Min.	35 Min.
Vertical Flow Tank D.	40 Minutes	1 Hr. 11 Min.	1 hour.

With the horizontal flow type of tank, the settling compartment consists of several hoppers depending upon the size of tank, which necessitate removing sludge from each hopper continuously thus increasing the supervision required for proper operation.

As the amount of sludge was insufficient to waste continuously the surplus was allowed to remain in the settling tanks, which was removed once or twice per day, depending upon how often the settling tank filled with sludge. When the sludge was removed, it was necessary to shut down the plant during this period; however the tanks were being aerated during these intervals. Immediately after starting the plant again, the effluent contained a small amount of floculent material in suspension. However, as soon as the sludge settled in the tank forming an even layer or blanket of sludge above the inlet, the effluent became clear, as the fine floculent and colloidal material in the sewage was filtered out in passing through this layer of sludge. If the layer of sludge rose too high and was less than one foot below the outlet trough, some fine sludge particles would be carried off with the effluent. The clearest effluent was obtained when the sewage passed through a sludge blanket of about three feet which acts as a filter medium and arrests the fine material in suspension as well as some of the colloidal material. This sludge layer can easily be maintained in a large plant where sufficient sludge is formed, so that the excess can be removed continuously.

SLUDGE CIRCULATION.

When operating the sludge pumps, the sludge circulation is controlled by a valve on the discharge line from the pumps, before entrance into the orifice box. The results have been very uniform. Even with the small size pumps in use only very occasionally cleaning has been necessary to remove fibrous matter around the shaft and runner. Considering the nature of the sludge this is practically no clogging. Most of the heavy coarse matter in the raw sewage is caught by the rotary screen. The best working results to the sludge piping have been secured with the entrance in the tank looking up.

There is less likelihood of trouble with operating air lifts

as there are no mechanical parts to get out of order and less chance of clogging. The sludge circulation is controlled by a valve on the air line. The results have been very uniform. The air used for lifts does not require washing and should be taken from a receivertank, so as to avoid the pulsating effect of the blower. Best results were obtained with the air entering thru a perforated plate or screens of the same diameter of the pipe.

SLUDGE RATIO.

The ratio of the sludge to the sewage flow is an important factor, though difficult to control. The amount of sludge returned decreases the available capacity of the aerating tanks, and increases the amount of power and size of pumping units which return the sludge. The ratio as determined by volume will depend solely on the moisture content ofthe sludge returned. This is also related to the settling qualities of the sludge.

During the period July 2 to 11, the ratio of sludge flow to sewage was 0.76, a high figure, owing to the presence on the first day of only 14 per cent of sludge after 1 hour settling in 100 c.c. cylinders. Such flowsreturn all the sludge with a considerable amount of treated sewage.

The average per cent of sludge in the last tank (tank 6) as determined by volume after settling 1 hour in 100 c.c. cylinders, is taken as the basis for calculation. Further settling does not materially decrease the sludge volume in warm weather, when the sludge is in good condition. On the other hand, the per cent of sludge decreases considerably in the other three aerating tanks after the first hour settling. In cold weather, there is very little difference in the rate of settling of the sludge in the different tanks, the rate being slowest in tank 6. There is an appreciable decrease in the per cent of sludge in all the tanks in cold weather after 1 hour. During the cold weather, a higher sludge per cent was maintained in the aeration tanks. During run #1, the average per cent of sludge for the period was 29, also high, on account of the slow settling properties of the sludge on several days.

During run #2, the sludge setttled well, maintaining an average of 19 per cent by volume, in the tanks, as tested after 1 hour settling. When the sludge settled well, the ratio of flow to sewage was 0.50. The high air consumption, (4.41) cu. ft. per gallon sewage is due to the absence of a Sunday or holiday during the period. Probably a slight excess of air was supplied, above that actually required, as evidenced by the fast settling of the sludge.

During runs #3 and #4, the results obtained are the most valuable, because of the duration of the run. The sludge was in good condition at the start, but gradually lost its settling qualities, necessitating an increase in the air supply. The ratio of sludge flow was 0.48 on an average, altho on several days the ratio was lower. An average of 32% of sludge was maintained during this period.

During run #5, the condition of the sludge was satisfactory. The ratio of sludge return was 0.48, and 24% present in aeration tanks.

In run #6, a marked increase in the sludge return was noted, the ratio being 0.7. This was caused by the slow settling of the sludge, which was quite noticeable in the aeration tanks where 46% by volume was present.

As the colder weather set in, the sludge soon exhibited slower settling properties, which necessitated maintaining a higher per cent in the aerating tanks. This resulted in a material increase in the amount of sludge returned.

During Run #7, the sludge was satisfactory except during a short interval, when the sludge settled very slowly. There was an average of 48% in the aeration tanks, and the sludge ratio return was 0.69.

During Runs #8 and #9, the sludge settled much slower on account of the colder weather. An average of 31% was maintained in the aeration tanks, and the average sludge ratio was 0.66.

At the start of ~~sludge~~ run #10, there was too much sludge in the tanks so no sludge was pumped for a short period, and the amount of sludge returned was reduced. During this period considerable more sludge was disposed of than the equivalent reduction of suspended matter. (Refer to sludge quantity). For this reason, the sludge ratio was reduced to 0.49, and there was 58% in the aeration tanks.

During Run #11, the sludge settled a little faster. The ratio of sludge return was 0.54, and there was 25% in the aeration tanks.

From Dec. 16, 1916 to Mar. 26, 1917, the plant was operated chiefly to obtain clarification resulting in an inferior effluent of fairly low stability. The sludge exhibited very slow settling properties, which resulted in a material increase in the sludge return. The following sludge ratios with corresponding sludge per cent in aeration tanks were recorded.

No. of Run	Ratio of Flow $\frac{\text{Sludge}}{\text{Sewage}}$	Average % in Tank #6 Settled 1 Hour.
12	0.66	25
13	0.93	19
14	0.79	28
15	0.67	20

ANALYTICAL RESULTS.

The analytical results have been tabulated for each run, keeping separate the results for day, night, Sunday and holiday. Averages have been computed for the day and night samples combined, as well as day, night, Sunday and holiday combined. Tables have been made of these summaries, as well as tables for the per cent reduction, of the various chemical constitutents, tables #4 and #5.

The strength of the crude sewage varied considerable from month to month, increasing during the fall and reaching a maximum in run #10 (Nov. 24 - Dec. 10, 1916). These results are consistent with those found in Report on Industrial Waste (pages 40-44). The strength of the sewage varying with the amount of slaughtering and packing in the packing houses. The increase in the strength of the sewage during the fall and winter must be taken in consideration when comparing the results.

In general the effluentsof the settling tank have been clear, although at times flows of sludge are carried over. Temperature is a very important factor in governing the degree of nitrification. The rate of nitrification being much greater in warmer weather due to greater activity of the nitrifying bacteria. The reduction of total suspended matter has been high at all times. A study of the tables clearly indicates that there was a decided change in the rate of nitrification during run #8, Oct. 15 to 22, 1916. The average temperature during this run was 49°·F. In discussing the results, the warm weather period will be considered extending to ~~the~~ run #8, the cold weather period will be taken for the remainder of the runs. However this change was gradual, and the critical temperature was about 50° F.

During the warm weather the reduction of organic nitrogen was high throughout the entire period (Run #1 to #8). Nitrification has progressed fairly well, although the nitrogen cycle was not completed. The reduction of free ammonia was fairly high during July, which however, decreased gradually, the % reduction in run #1 was 67.0%, while in run #7 - 37.8%. The nitrite and nitrate content being quite appreciable, with the nitrite content relatively large compared to the nitrate. The completion of the nitrogen cycle is not essential to the operation. As the removal of suspended matter and increase in stability are sufficient, if the reduction in organic nitrogen and free ammonia and the increase in nitrites and nitrates are pronounced.

During the cold weather, the reduction of organic nitrogen was fairly high throughout the entire period (Run #8 to #15), however the per cent reduction was slightly lower than during warm weather. Nitrification progresses much slower than in warmer weather. There is a marked increase in the free ammonia content contrary to the reduction in warm weather. Nitrites and Nitrates are only present in small amounts.

Dissolved Oxygen tests were started during run #8 and B.O.C. (Saltpeter method) determinations started during run #9. The majority of the samples tested contained dissolved Oxygen, the content however increasing with the decrease in temperature. The B.O.C. values varied with the total suspended matter and organic nitrogen content. An increase in these two constituents was noticeable by an increase of the B.O.C. value.

During the warm weather, the relative stabilities have been satisfactory in general, the majority of the hourly samples having been stable. The figures are based on samples kept for 10 days at room tenperature. If blue at that time, the samples is rated at 100. Starting with run #6, relative stability samples were taken from the effluent end of tanks #5 and #4, and are equivalent to an effluent

receiving 0.75 and 0.50 respectively of the amount of air the final effluent receives. Generally the samples of tank 5 were nearly as stable as the final effluent, while those from tank 4 were considerably lower. The relative stability samples were taken from a sampling device connected directly to the effluent trough of the settling tank, while tank #5 and #4 samples received 1/2 hour to 1 hour quiescent settling in sampling cans before samples were taken.

These results seem to indicate that a saving of air could be made by a reaeration of the sludge before returning to the system. Very frequently individual samples show low stabilities, probably due to the presence of sludge in the samples, which had escaped with the effluent. Occasionally poor results occurred in samples free from sludge and clear. These may be "freaks" or due to sudden changes in the strength of the sewage. During the cold weather runs, the relative stabilities were generally low, as the purpose of the tests was to get clarification, without stability. However, the air consumption in colder weather is much higher, if a stable effluent is desired.

The reduction in suspended matter would have been greater, if all the sludge could have been retained in the settling tanks. This is not properly chargeable to the process, but to the design and operation of the settling tank. The effect of the operation has been discussed under SETTLING TANKS. However, the sludge is light and hard to settle except at low vertical velocities.

In general the chemical results have been quite consistent, although individual variation in analyses are occasionally large. The stability results bear a relation to the amount of air used; however during warm weather, the stability is obtained with a clarified effluent, while in cold weather clarification is obtained much sooner than the stability. The increase in air consumption in cold weather is due to the low temperature as well as the increased strength of crude sewage.

SLUDGE.

Typical activated sludge from Packingtown sewage is brown in color and settles fairly quickly, usually in one half hour, reaching a minimum, approximately in one hour, leaving a very distinct line of demarkation between the clear liquid and the sludge. At the end of three hours, the per cent of sludge will decrease only about two per cent. Daily tests have been made of the settling qualities of the sludge from the different tanks.

The result on July 13, 1916, at 8 A.M. are typical during warm weather and are as follows:

HOURS SETTLING	SLUDGE % IN TANK NO. 3	4	5	6
0.25	88	88	71	55
0.50	69	69	44	32
1	46	45	27	26
2	19	21	23	24
3	17	19	21	23

These results in 100 c.c. cylinders show that the sludge settled much faster in tank #6 than in the other tanks. The settling qualities also improve from tank 3 to tank 6, in proportion to the period of contact in aeration. The sludge from tank 6 has practically completed settling in one hour.

In cold weather the sludge does not settle as fast, and the rate of settling does not increase in the different tanks from tank 3 to tank 6, but on the contrary the rate of settling varies in the opposite direction, tank 3 settling faster than tank 6. The results on Dec. 24, 1916 are typical during cold weather when operating for clarification only, and are as follows:

HOURS SETTLING	SLUDGE % IN TANK NO. 3	4	5	6
0.25	33	43	50	60
0.50	24	30	35	39
1	20	24	28	29
2	16	20	22	22
3	13	15	18	19

Sludge which has been over aerated in winter has a pale straw color, settles very fast and is accompanied by a loss of flocculence. A typical example of over aerated sludge occurred on Dec. 25 and 26, 1916. The following table indicates the effect upon the settling qualities of over aerated sludge.

HOURS SETTLING	SLUDGE % IN TANK #6 DATE Dec. 24	Dec. 25	Dec. 26	Dec.27	-28
0.25	60	16	8	22	27
0.50	39	14	6	16	23
1	29	11	5	16	18
2	22	9	5	10	13
3	19	5	4	8	11

As the sewage was very weak on Dec. 24 (SUNDAY) and Dec. 25 (holiday) and although the air was materially reduced on Dec. 25, nevertheless the sludge received too much air, which increased its settling qualities as well as changed its physical appearance. Two days aeration with sewage and a reduced air consumption were sufficient to return the sludge to its normal state.

In warm weather the amount of air also has a very direct effect on the settling quality of the sludge. Starting with a sludge of good normal quality, a decrease of air will gradually be accompanied by a change in color, to a lighter color, a loss of flocculence and a slower subsiding value.

The per cent of sludge recorded on settling for definite periods in 100 c.c. cylinders, are not comparable from day to day, as the settling qualities of activated sludge vary with its state of activat-

ion, as well as the temperature.

SLUDGE TREATMENT.

The activated sludge process produces an enormous volume of very liquid sludge, which must be handled while comparitively fresh, as the sludge becomes septic in a very short time. The various methods suggested for treatment are as follows: Concentration, reaeration followed by separate sludge digestion, lagooning, air drying on sand beds, acid concentration, yeast fermentation (developed at Dublin), filter pressing and heat drying.

Experiments have been conducted on air drying on sand beds, lagooning, concentration and acid concentration.

Normal activated sludge will not dry as quickly as Imhoff tank sludge. When activated sludge is applied to sand beds, considerable water passes through under drains, while filling and for a short while thereafter. However, within a very short time after the bed is filled, the sludge settles to the bottom very rapidly, forming a mat of sludge on the surface of sand which materially decreases the amount of water passing through sand into under drains. After remaining on bed overnight, with a 24 inch dose, about four inches of water will have passed through under drain, and about 14 or 15 inches of clear liquid can be siphoned off of surface of sludge bed leaving 5" to 6" of concentrated sludge on the bed, which dries very slowly. The sludge ~~air~~ drying develops a large number of small cracks. The results obtained have not been consistent on account of frequent rains; however the most promising results obtained were with sludge applied to beds on Sept. 12 and removed on Sept. 19. In this test 24" of sludge of 99.3% moisture content was applied, which was reduced to 76.1% in 7 days, during which period there was a rainfall of .03 inch, (experiments have been started using sand beds covered with glass, the results of which are not available at the present time).

Lagooning of the sludge has been tried, and has been found unsuccessful. As from properties noted above, the sludge settles to the bottom and water remains on top, which must be siphoned off before the sludge will be given an opportunity to dry. The sludge dries much faster on beds on account of the under drains which remove the water. To successfully treat sludge by lagooning, under drains must be supplied as well as means for removing the water from surface of sludge, which will then be similar to sand beds.

As the sludge has considerable more value as a fertilizer than any other sludge, the only method demonstrated at present to successfully recover the sludge on a practical basis has been by filter pressing and heat drying. As preliminary concentration seems to be essential to remove as much water as possible, a series of experiments have been conducted in sludge concentration in tanks of different depths. Two galvanized iron tanks (A & B) were used for these tests.

THE SANITARY DISTRICT OF CHICAGO
ACTIVATED SLUDGE CONCENTRATION IN TANKS OF DIFFERENT DEPTHS.

Tank A.... Diam. - 2.0 ft. - Depth 19.85 ft.

Tank B.... Diam. - 2.0 ft. - Depth 9.0 ft.

Activated sludge from settling tank (D) was pumped into the bottom of tanks A and B by means of a 1-1/2 inch centrifugal pump. The inlet to the tanks was in the center of the bottom so as to prevent the sludge from settling while filling. Tank A which was filled first, required 20 to 30 minutes, while tank B required 10 to 15 minutes. A composite sample of the sludge was taken while filling both tanks, while separate composite samples from each tank were taken while emptying. Moisture analyses were made on these samples.

The sludge usually settled very evenly leaving a sharp line of demarcation between the sludge and supernatant liquid. The depth of the sludge was measured with a stick graduated to tenths of a foot and which contained five small wide mouth bottles. The stoppers of these bottles were connected to the top of stick by two cords. When measuring the sludge the bottles were lowered into the tank, and all the stoppers withdrawn at the same time at any desired depth. Usually one or two trials were sufficient to determine the sludge line, as each immersion recorded the sludge for a depth of one foot. Sludge levels were taken as soon as the tanks were filled, every 15 minutes thereafter for the first hour, every 1/2 hour for the next 2 hours and hourly thereafter.

The results were recorded in Tables 6 and 7.

As the settling properties of the sludge varies from day to day and depend upon its physical appearance, state of activation and moisture content, care must be taken in drawing conclusions. The conclusions noted herein are based on a study of the individual tests.

With typical activated sludge, the rate of subsidence was much faster in tank B than in tank A during the first hour, after which the reverse was the case. The rate in tank B did not increase sufficient so as to produce the same results as in tank A in 3 to 4 hours which was generally the duration of the tests. The following table shows the percent concentration obtained in the tanks in 1 hour, 2 hours and 3 hour periods:

Sludge Removed

Da	Depth Feet	Per ct.	Gallons	Per ct. Moisture	Remarks.
Nov					
28	9.0	46	213		Sludge typical, settles fast
28	9.5	49	224		" " " "
29	7.8	40	184		" " " "
Dec					
4	7.0	36	165		Sludge settles fast
5	7.8	40	184		" " slow
5	13.9	71	328	98.77	" " "
6	12.2	63	288	98.78	" " very slow
6	10.2	52	241	98.96	" " " "
7	12.9	66	304	98.77	" " " "
11	5.4	28	127	99.00	" " " fast
12	5.6	29	132	98.85	" " " "
13	5.7	29	135	98.92	" " " "

settling.

No					
28	3.5	39	82		Same as Tank A.
Dec					
[illegible]	4.8	53	112		" " " "
[illegible]	5.7	63	133	98.87	" " " "
[illegible]	9.0	100	210		" " " "
11	3.2	36	75	99.01	" " " "
12	2.9	32	68	98.86	" " " "
12	2.5	28	58	98.92	" " " "

THE SANITARY DISTRICT OF CHICAGO

ACTIVATED SLUDGE EXPERIMENTS SLUDGE CONCENTRATION

Tank A - Depth 19.~~8~~ 85 ft. Diam. 2.0 ft. Volume - 460 Gals.

Date	Time Start Filling	Time Filled	Per Ct. Moisture Filled	Sludge Level A* - feet Start	15 min.	1/2 hr.	1 hr.	1½ hrs.	2 hrs.	2½ hrs.	3 hrs.	4 hrs.	5 hrs.	6 hrs.	Sludge Removed Depth Feet	Per ct.	Gallons	Per ct. Moisture	Remarks.
Nov.																			
28	8:00 AM.	8:35 AM.		9.8	11.8	11.8	11.8	11.8	11.8	11.8					9.0	46	213		Sludge typical, settles fast
28	11:50 AM.	12:25 PM.			5.8	9.3	9.8	10.0	10.3	10.6	10.7				9.5	49	224		" " " "
29	7:45 AM.	8:20 AM.		6.8	7.9	10.8	11.5	12.0	12.5	12.5	12.5				7.8	40	184		" " " "
Dec.																			
4	9:50 AM.	10:15 AM.		5.0	10.9	12.6	13.3	13.4	13.5	13.6	13.6	13.7			7.0	36	165		Sludge settles fast
5	7:35 AM.	8:00 AM.		5.6	7.5	10.8	11.8	12.3	12.3	12.3	12.3	12.5			7.8	40	184		" " slow
5	1:00 PM.	1:30 PM.	99.06	1.0	3.7	4.7	5.7	5.8	6.0	6.5	6.5				13.9	71	328	98.77	" " "
6	7:30 AM.	8:00 AM.	99.19	1.5	2.5	3.6	5.8	6.5	6.8	7.3	7.4	7.8			12.2	63	288	98.78	" " very slow
6	12:00 M.	12:30 PM.	99.16	1.0	3.0	5.5	8.2	8.9	9.2	10.0	10.0				10.2	52	241	98.96	" " " "
7	7:35 AM.	8:00 AM.	99.15			1.0	3.0	4.0	5.8	6.0	6.3	6.3	6.8	7.0	12.9	66	304	98.77	" " " "
11	9:05 AM.	9:30 AM.	99.59		3.0	5.0	8.0	11.0	13.3	13.8	14.8				5.4	28	127	99.00	" " " fast
12	7:50 AM.	8:15 AM.	99.43	1.0	3.5	6.5	10.5	12.0	13.0	14.0	14.5				5.6	29	132	98.85	" " " "
13	10:00 AM.	10:30 AM.	99.59	1.2	4.0	5.5	8.5	11.1	12.8	14.0	14.3				5.7	29	135	98.92	" " " "

NOTE:- *Sludge Level Ft. equals depth of clear liquid above sludge.

Results on Dec. 5, P.M., 6 & 7 are not typical, as sludge required further aeration to condition the same properly for settling.

Results on Nov. 28, 29, Dec. 4 & 5 A.M. are typical
" " Dec. 11, 12, 13 show very fast settling properties, due to excess air
Sludge level (Ft.) plus Sludge Removed (Ft.) > 19.85 Ft., due to method of removing concentrated sludge

Tank B - Depth 9.0 Ft. Diam. 2.0 Ft. Volume - 210 Gals.

Date	Time Start Filling	Time Filled	Per Ct. Moisture Filled	Sludge Level A* - feet Start	1/4 hr.	15 min.	1/2 hr.	1 hr.	1½ hrs.	2 hrs.	2½ hrs.	3 hrs.	4 hrs.	5 hrs.	6 hrs.	Sludge Removed Depth Feet	Per ct.	Gallons	Per ct. Moisture	Remarks.
Nov.																				
28	12:25 PM.	12:35 PM.			5.4	6.0	6.0	6.1	6.1	6.2	6.2					3.5	39	82		Same as Tank A.
Dec.																				
5	8:00 AM.	8:15 AM.			3.0	3.9	4.3	4.5	4.5	4.5	4.6	4.6				4.8	53	112		" " " "
6	8:15 AM.	8:30 AM.	99.19				2.8	3.2	3.4	3.5	3.5	3.5	3.5	3.5		5.7	63	133	98.87	" " " "
7	8:15 AM.	8:30 AM.	99.15									0.2	0.2			9.0	100	210		" " " "
11	9:45 AM.	10:00 AM.	99.59	0.5		3.0	5.0	6.0	6.2	6.2	6.5	6.5				3.2	36	75	99.01	" " " "
12	8:15 AM.	8:30 AM.	99.43			1.0	3.5	5.5	6.0	6.4	6.5	7.0				2.9	32	68	98.86	" " " "
13	10:45 AM.	11:00 AM.	99.59			1.5	4.2	6.2	6.6	6.8	7.0	7.2				2.5	28	58	98.92	" " " "

Table 2.

THE SANITARY DISTRICT OF CHICAGO
SLUDGE CONCENTRATION EXPERIMENTS

TANK A. - DEPTH 19 Ft. 10 In. - DIAM. 2 Ft. 0 In. - VOLUME - 467 GALLONS.

Date 1917	Time Start Filling	Time Filled	Per Ct. Moisture Filled	Sludge Level - Feet Start	1/4 Hr.	1/2 Hr.	3/4 Hr.	1 Hr.	1-1/2 Hr.	2 Hr.	2½ Hr.	3 Hr.	4 Hr.	5 Hr.	6 Hr.	Sludge Removed Depth Feet	Per Ct.	Gallons	Per Ct Moisture	Remarks
Jan. 4	11:00 AM.	11:20 AM.	99.66	0	1.0	3.5	5.0	7.5	9.7	12.0	14.0	15.5	15.9			4.4	22	103	99.09	Sludge typical
" 5	10:00 AM.	10:20 AM.	99.54	0	1.0	2.5	5.0	6.0	9.5	12.0	13.0	13.3	14.2	14.9		5.3	27	125	98.47	" "
" 6	10:30 AM.	10:50 AM.	99.47	0	1.0	3.0	4.0	5.0	7.5	9.5	10.5	11.5	12.6			7.6	38	179	97.94	Sludge settle slower
" 8	9:00 AM.	9:20 AM.	99.53	1.0	2.5	4.0	5.5	6.5	9.5	11.5	11.5	12.0	12.2	13.0	13.2	6.8	34	160	98.25	Sludge typical
" 9	8:30 AM.	8:50 AM.	99.41	1.2	3.0	3.5	5.0	6.5	9.5	11.0	11.8	12.2	13.2	14.0	14.5	5.7	29	134	98.35	" "
" 10	8:30 AM.	8:50 AM.	99.30	0.5	0.8	0.8	1.0	1.8	3.0	3.8	4.8	5.5	7.3	8.0	8.8	11.2	56	263	98.71	Sludge settles slower
TANK B. - DEPTH 9 Ft. 0 In. - DIAM. 2 Ft. 0 In. - VOLUME - 210 GALLONS																				
" 4	11:35 AM.	11:45 AM.	99.66	0	0.5	2.5	4.0	5.5	6.5	7.0	7.3	7.3	7.5			2.0	22	47	98.83	Same as Tank A.
" 5	10:20 AM.	10:30 AM.	99.54	0	0.5	2.0	3.7	5.0	6.0	6.3	6.3	6.5	6.5	6.8		2.0	22	47	98.39	
" 6	10:50 AM.	11:00 AM.	99.47	0	0.5	2.2	3.5	4.0	5.3	5.7	6.0	6.0	6.5			2.7	30	63	98.52	
" 8	9:20 AM.	9:30 AM.	99.53	0	0.8	2.2	3.0	3.5	4.2	4.5	4.8	5.0	5.0	5.2	5.5	4.7	52	110	98.32	
" 9	8:50 AM.	9:00 AM.	99.41	0	1.3	3.0	4.5	4.8	5.5	5.8	6.0	6.2	6.5	6.5	7.0	2.3	26	54	98.52	
" 10	8:50 AM.	9:00 AM.	99.30	0	0	0.6	1.0	1.5	3.0	3.5	4.0	4.3	5.0	5.0	5.5	3.5	39	82	98.77	

Tank A.

19.85 Ft. Deep

Date	% Concentration 1 hr.	2 hrs.	3 hrs.
1916			
Nov. 28	51	48	46
Dec. 5	42	38	38
" 6	71	66	63
" 11	60	33	25
" 12	47	35	27
" 13	57	36	28
1917			
Jan. 4	62	40	22
" 5	70	40	33
" 6	75	52	42
" 8	67	42	40
" 9	67	45	39
" 10	91	81	72

Tank B.

9.0 Ft. Deep

Date	% Concentration 1 hr.	2 hrs.	3 hrs.
1916			
Nov. 28	33	32	31
Dec. 5	52	50	49
" 6	69	62	61
" 11	33	31	28
" 12	39	29	22
" 13	31	24	20
1917			
Jan. 4	39	22	19
" 5	44	30	28
" 6	55	37	33
" 8	61	50	44
" 9	47	36	31
" 10	83	60	52

In tank A the difference between the degree of concentration for 2 hour and 3 hour periods is not very great and does not seem to warrant the expenditure of providing for over a 2 hour period for sludge concentration. In tank B the results on Nov. 28, Dec. 5,6,11, the 2 hour results show very little improvement over those of 1 hour, while the remaining tests show an appreciable concentration during the second hour, but very little concentration during the third hour. In referring to the complete concentration tables 8 and 9, the results on these latter dates show very little concentration after 1-1/2 hours.

Generally an equivalent concentration is obtained in tank B in 1 hr. and 1-1/2 hr. respectively to that obtained in tank A in 2 hrs. and 3 hrs. respectively.

CONCLUSIONS.

1. The rate of concentration of typical activated sludge is much greater in a tank 9 ft. deep than in one 19.85 ft. deep during the first hour, after which the reverse is the case.

2. The concentration effected in a period of 1 hour in the shallow tank is equivalent to a 2 hour period in the deep tank.

3. A slightly greater concentration takes place in the 9 ft. depth tank in 4 hours than in the deeper tank.

4. The most economical concentration can be secured with a tank 9 ft. deep, and with a detention period of 1-1/2 hours.

Further experiments along these lines should be conducted, so as to obtain additional information as to the design of concentration tanks.

Table 8.

THE SANITARY DISTRICT OF CHICAGO
SLUDGE CONCENTRATION EXPERIMENTS

Date 1916	Tank	Pr. Ct. Moisture	Per Cent Concentration*								
			Start	¼ hr.	½ hr.	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	4 hr.
Nov. 28	A			71	53	51	49	48	47	46	
	B			40	33	33	32	32	31	31	
	Diff.			31	20	18	17	16	16	15	
Dec. 5 See Note #	A		72	62	46	42	38	38	38	38	37
	B			67	57	52	50	50	50	49	49
	Diff.			-5	-11	-10	-12	-12	-12	-11	-12
Dec. 6	A	99.19	93	87	82	71	67	66	63	63	61
	B	"				69	64	62	61	61	61
	Diff.					2	3	4	2	2	0
Dec. 11	A	99.59		85	75	60	45	33	30	25	
	B	"	94	67	44	33	31	31	28	28	
	Diff.			18	31	27	14	2	2	-3	
Dec. 12	A	99.43	95	82	67	47	40	35	29	27	
	B	"		89	61	39	33	29	28	22	
	Diff.			-7	6	8	7	6	1	5	
Dec. 13	A	99.59	94	80	72	57	45	36	29	28	
	B	"		83	53	31	27	24	22	20	
	Diff.			-3	19	26	18	12	7	8	

NOTE.-

* Per cent concentration calculated as percent sludge volume remaining after various detention periods.

\# Test on Dec. 5 seems to be a freak result, as it does not agree with observations noted and also the afternoon test.

Table 8.

THE QUALITATIVE EFFECTS OF DRINKING
UPON DISCRIMINATION PERFORMANCE

Ss	Week	Vol.	Effect	Perf.	Perf.	Perf.	Perf.	Perf.	Perf.
V. 28	A			71	53	61	46	46	47
	B			40	55	[illegible]	32	32	[illegible]
	Diff.			31	20	12	17	16	12
S. 8	A		73	65	45	42	28	38	[illegible]
	B			67	57	32	39	25	26
to	Diff.			-2	-11	-10	-12	-13	[illegible]
S. 6	A	90.19	58	67	62	71	67	66	[illegible]
	B					59	64	52	41
	Diff.					9	3	4	1
S. 11	A	79.59		58	75	60	46	50	50
	B		84	47	44	[illegible]	41	1	[illegible]
	Diff.			18	31	27	14	3	7
S. 12	A	99.45	[illegible]	55	67	47	43	38	[illegible]
	B			59	61	39	[illegible]	49	[illegible]
	Diff.			-7	6	8	7	6	1
S. 13	A	99.50	84	80	72	87	44	39	[illegible]
	B			88	73	71	47	54	[illegible]
	Diff.			-8	1	16	1	15	7

10.-

[illegible] per cent concentration calculated on weekly [illegible] val[illegible] remaining after various extraction methods.

[illegible] test on Ss. 8 seems to be a true result, as indepen[illegible] with observations noted and also the extension test.

Table 9.

THE SANITARY DISTRICT OF CHICAGO
SLUDGE CONCENTRATION EXPERIMENTS

Date 1917	Tank	Per Ct. Moisture	Per Cent Concentration											
			Start	1/4hr.	1/2hr.	3/4hr.	1 hr.	1½ hr.	2hr.	2½hr.	3 hr.	4 hr.	5 hr.	6 hr.
Jan. 4	A	99.66	100	95	82	75	62	51	40	30	22	20		
	B	"	100	94	72	56	39	28	22	19	19	17		
	Diff.		0	1	10	19	23	23	18	11	3	3		
Jan. 5	A	99.54	100	95	87	75	70	52	40	35	33	28	25	
	B	"	100	94	78	59	44	33	30	30	28	28	25	
	Diff.		0	1	9	16	26	19	10	5	5	0	0	
Jan. 6	A	99.47	100	95	85	80	75	62	52	47	42	37		
	B	"	100	94	76	61	55	41	37	33	33	28		
	Diff.		0	1	9	19	20	21	15	14	9	9		
Jan. 8	A	99.53	95	87	80	72	67	52	42	42	40	39	35	34
	B	"	100	91	76	67	61	53	50	47	44	44	42	39
	Diff.		-5	-4	4	5	6	-1	-8	-5	-4	-5	-7	-5
Jan. 9	A	99.41	94	85	82	75	67	52	45	41	39	33	29	27
	B	"	100	86	67	50	47	39	36	33	31	28	28	22
	Diff.		-6	-1	15	25	20	13	9	8	8	5	1	5
Jan. 10	A	99.30	97	96	96	95	91	85	81	76	72	63	60	56
	B	"	100	100	93	89	83	67	60	56	52	44	40	39
	Diff.		-3	-4	3	6	8	18	21	20	20	19	20	17

Table 3.

THE SANITARY DISTRICT OF CHICAGO
DAILY FLOW DURING [illegible]

Date 1917	Hour	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow
Dec. 6	1	77.44	100	95	80	75	67	62	60	58	50		
	2		100	94	78	76	65	58	56	52	47		
	Diff.		0	1	2	1	2	4	4	6	3		
Dec. 7	1	94.44	100	95	87	74	70	67	64	62	58	58	
	2		98	94	79	74	64	62	59	56	52	52	
	Diff.		2	1	8	14	16	10	9	6	6	6	
Dec. 8	1	103.47	100	98	88	80	75	72	67	64	57		
	2		100	94	78	72	62	57	53	51	50		
	Diff.		0	1	8	12	13	15	14	9	9		
Dec. 9	1	99.25	98	87	77	67	60	45	42	40	38	38	34
	2		100	97	87	72	67	50	47	44	42	40	39
	Diff.		2	4	8	5	7	5	5	4	5	2	5
Dec. 10	1	104.0	94	90	78	67	62	47	45	42	40	37	
	2		100	96	87	77	70	61	59	51	50	50	
	Diff.		6	6	10	10	8	14	14	9	10	13	
Dec. 10	1	99.00	97	95	91	86	81	76	66	60	58		
	2		100	98	93	87	80	75	64	60	59		
	Diff.		3	3	2	1	1	7	10	12	10	17	

SLUDGE QUANTITY.

A summary of the accumulation of the sludge for the different periods is tabulated in Table #10. During July the results are misleading, since in the early part of the month no sludge was wasted on account of the small amount in the aeration tanks. During the entire time 17,190,150 gallons of sewage were treated with an accumulation of sludge equivalent to 2,420 dry pounds or 46,500 gallons per million gallons of sewage treated. The moisture content of the sludge is lower in warm weather being about 99.0% while an average of about 99.5% is maintained during the cold weather.

In calculating the equivalent dry weight of sludge from the moisture content, due allowance was made for the solids in solution. An analyses of several samples of the supernatant liquid were made, and an average of 2000 p.p.m. or 0.2% solids in solution were found. The error resulting from this source is considerable when the moisture content of the sludge is over 99%, while with a moisture content as low as 80% the error is only 1%. The following table shows the percent error corresponding to different moisture contents, where the solids in solution average 0.2%.

MOISTURE PERCENT.	PERCENT ERROR.
99.8	100
99.7	67
99.6	50
99.5	40
99.4	33
99.2	25
99.1	22
99.0	20
98.0	10
96.0	5
80	1

A summary showing the relationship between the reduction of total suspended matter and the accumulation of sludge from Sept. 17,1916to Mar. 26, 1917, are noted in Table #11. During this period 12,529,650 gallons of sewage were treated, with an equivalent reduction of 2820 dry pounds of total suspended matter and an accumulation of 2680 dry pounds of activated sludge.

From these figures we learn that 95% of the total pounds reduction of suspended solids entering the aeration tanks were recovered as dry pounds of activated sludge. The total suspended matter results in the summary table are expressed in parts per million, and are true averages with day, night, Sunday and holiday samples weighted according to their respective flows.

SLUDGE ANALYSES.

Analyses of the sludge were made weekly (tables #12 and 13) The nitrogen content has varied from 2.88% to 5.6%, the average being 4.17%, calculated on a dry basis, and is lower than quoted for other

plants.

Results seem to indicate that the nitrogen content increases when the mineral matter of the sludge decreases. The nitrogen content of the sludge is slightly lower during the period the screen was not operated (Run #7). The nitrogen content of activated sludge is considerable higher than sludge found in the settling tanks described in the Report on Industrial Wastes. This is brought from following table.

COMPARISON OF SLUDGE ANALYSES.

SLUDGE	Sp. Gr.	Percent Moisture	Calculated to Dry Weight Percent			
			Nitrogen	Volatile	Fixed	Ether Soluble
Activated Sludge	1.004	99.15	4.17	62.6	37.4	6.0
Einscher Tank	1.02	91.5	2.72	65	35	6.6
Dortmund Tank D.	1.02	91.7	2.88	76	24	8.6
Dortmund Tank C	1.02	90.6	2.65	72	28	8.1

The results indicate that the activated sludge is a far more watery mixture, somewhat lower in ether soluble constituents, with a lower proportion of volatile matter than the other sludges.

SCREENS.

During the operation of the plant on a continuous basis all the day sewage was passed through a 30 mesh rotary screen of the Weand type. This was operated from 7 A.M. to 9 P.M. except on Sundays and holidays. On Sept. 16, the screen was shut down, the plant being operated during run #7 to note the effect of the increased coarse solids on the aeration system and operation in general.

Considerable difficulty was experienced with clogging, especially during the early part of July, when an average of only 230 pounds of dry screenings were caught per million gallons of sewage. When the screen became clogged, the sewage would overflow the ends at the bottom, instead of passing through the screen. During the latter part of July and early August, better results were obtained by washing the screen occasionally with water under pressure, in addition to the regular automatic washing. During the end of August and early September, the screen was regularly scrubbed on Sundays with a hot solution of soda ash. This removed the grease and produced a good results throughout the week. In August an average of 516 pounds, and from Sept. 1 to 17, an average of 620 pounds of dry screenings, were obtained per million gallons of sewage. The increase retention was probably due to the improved efficiency of the screen, caused by cleaning.

A summary of the operating results are tabulated in table #14. There was a marked increase in the recovery during the cold weather,

reaching a maximum during the period Nov. 24,1916 - Jan. 8, 1917, when an average of 1280 pounds of dry screenings were obtained per million gallons of sewage. This increase was due to the increase in strength of the crude sewage during this period. The results indicate a fairly high use of water, 10.5 to 29.0 percent for washing purposes on the daily routine, during the time the screen is actually running. Undoubtedly a larger screen of this type could be cleaned to better advantage with a lower use of wash water. Large screens should be fitted with facilities for cleaning with steam, because a screen of 30 mesh clogs very rapidly.

The screenings are of the character described in the Report on Industrial Wastes, consisting largely of hay, chaff, paunch manure, undigested food particles, hair, bits of skin and flesh, and similar materials.

Weekly composited samples were analyzed and are tabulated in table #15. The composition is largely organic with an average of only 4.7% of mineral matter. The total nitrogen is 2.18%, being considerable lower than that of activated sludge, as well as lower than other sludges noted in table page 23. The ether soluble content of 5.93% is very similar to that of the activated sludge.

The following results were obtained in 1913 and 1914, (Report on Industrial Wastes, tables 78 & 79).

Period Year	Month	Moist Screenings Percent Moisture	Dry Screenings Lbs. per Million Gal.
1913	- Oct.20-Dec.10	86.4	950
1914	- May 1 - 31	80.7	500

The moisture content of 80.7% averaged slightly lower than that in 1913, but was the same as that in 1914. No results were obtained during May 1916, so comparable figures were not obtained; however during the period Oct. 20 - Dec. 10, 1916, the amount of screenings caught was slightly larger than the 1913 period, when the screen was only operated 7.1 hours a day.

The necessity for screening Packingtown sewage previous to passing through the aeration tanks is very essential. From the nature of the screenings obtained as well as from observations noted during the operation, this material undergoes very little change in passing through the tanks, its presence being noted in the sludge. Additional air is undoubtedly required to keep the screenings in suspension, and preventing the same from settling onto the filtros plates and causing a clogging of them. A screen of 20 mesh or equivalent slots would undoubtedly retain all this material.

CONCLUSION:

Average summaries of the operation and analytical results are noted in tables #16 and #17. A satisfactory and stable effluent can be obtained at all times disregarding the weather conditions, however the air consumption is higher in the winter, due to the

increase in strength of sewage as well as decrease in temperature. The operation can be made very flexible, as it is possible to obtain an effluent of any degree of stability. It is not necessary to aerate the sludge to a complete state of activation when operating for clarification only.

The amount of sludge recovered depends solely on the reduction of the total suspended matter, as practically all of the latter is converted into activated sludge. The sludge has a very high moisture content, exceeding 99%, thus necessitating the handling of large volumes, which must be done immediately, as the sludge becomes septic in a very short time. The sludge can be marketed as a low grade fertilizer, and results obtained from other plants seem to indicate that the sludge can be sudcessfully dewatered by concentration, filter pressing and heat drying. Experiments have not been conducted on pressing or heat drying.

The ~~expert~~ strength of the sewage varies considerable depending primarily upon the working hours in the different packing concerns. During nights and on Sunday, a very much weaker sewage is obtained. There is also a seasonable variation of the day sewage, as noted previously.

As the primary cost of operation is the cost of air, and as the air consumption is a variable factor depending upon the strength of sewage and character of sludge, too much stress cannot be made of the necessity for expert supervision at all times.

LIST OF TABLES.

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1.	Division of operation into periods.
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4.	Analytical Results July 2, 1916 to Mar. 27,1917.
5.	" " ,percent reduction, July 2,1916 to Mar.27 1917.
6.	Sludge Concentration Results, Tanks A. & B.
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10.	Sludge Accumulation.
11.	Relationship between reduction of total suspended matter and the accumulation of sludge.
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List of Drawings and Curves.

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4.	Tanks C,D, and 7.
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5-A.	Curves showing relationship between depth and volume of tanks.
6.	Tank 8.
7.	Curve-Flow Test Tank D, Feb.15,1917.
8.	" " " " ", Feb. 26,1917.
9.	" " " " 8, Jan. 10,1917.

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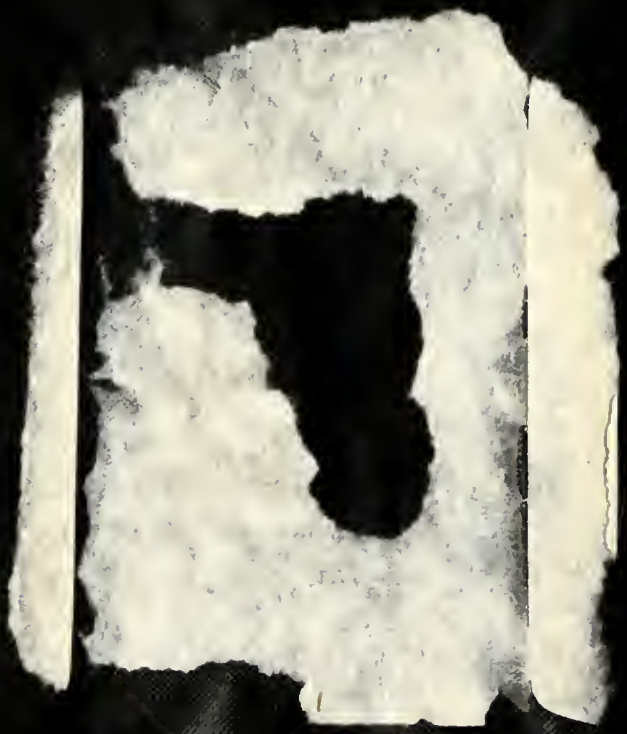
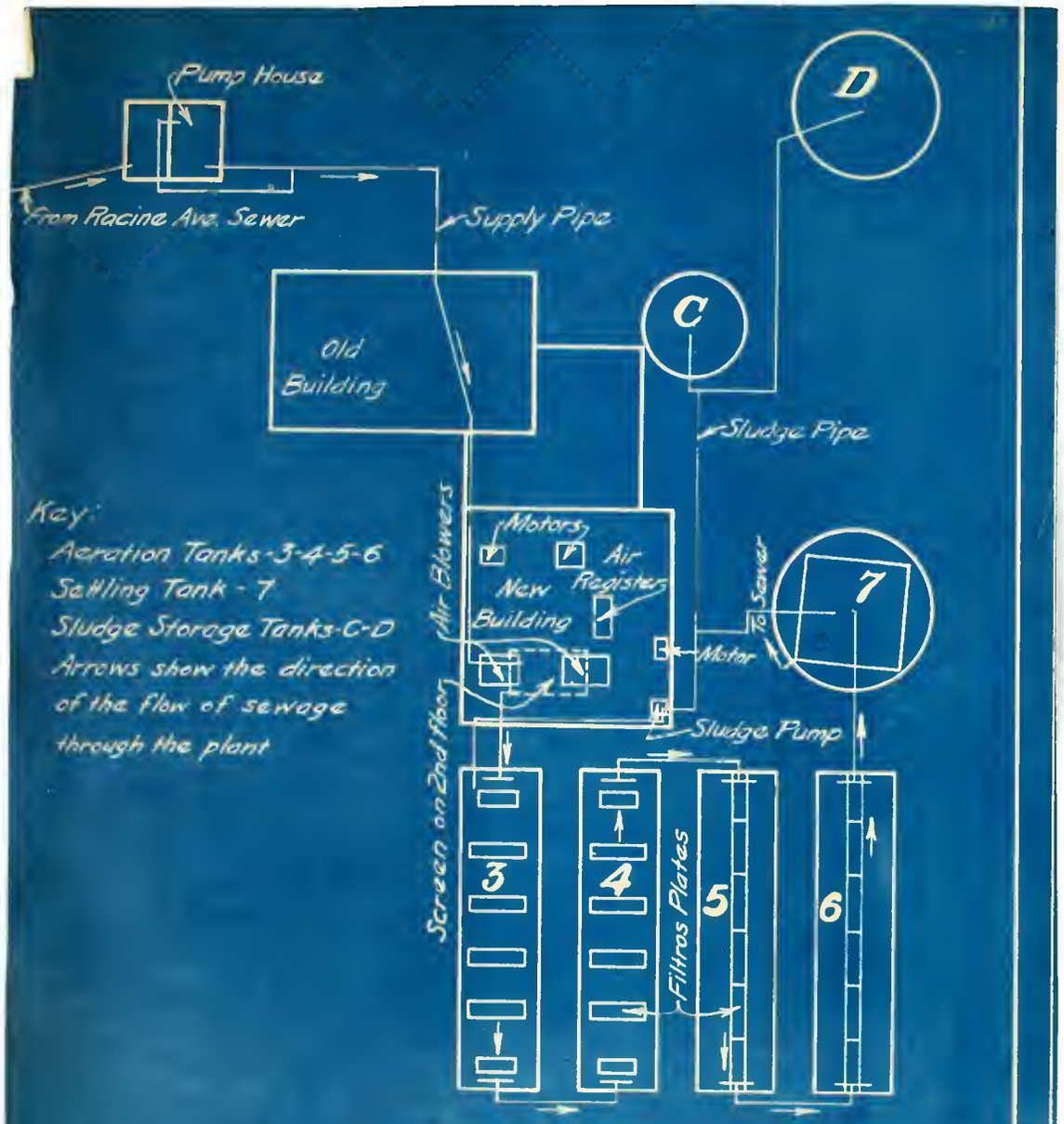


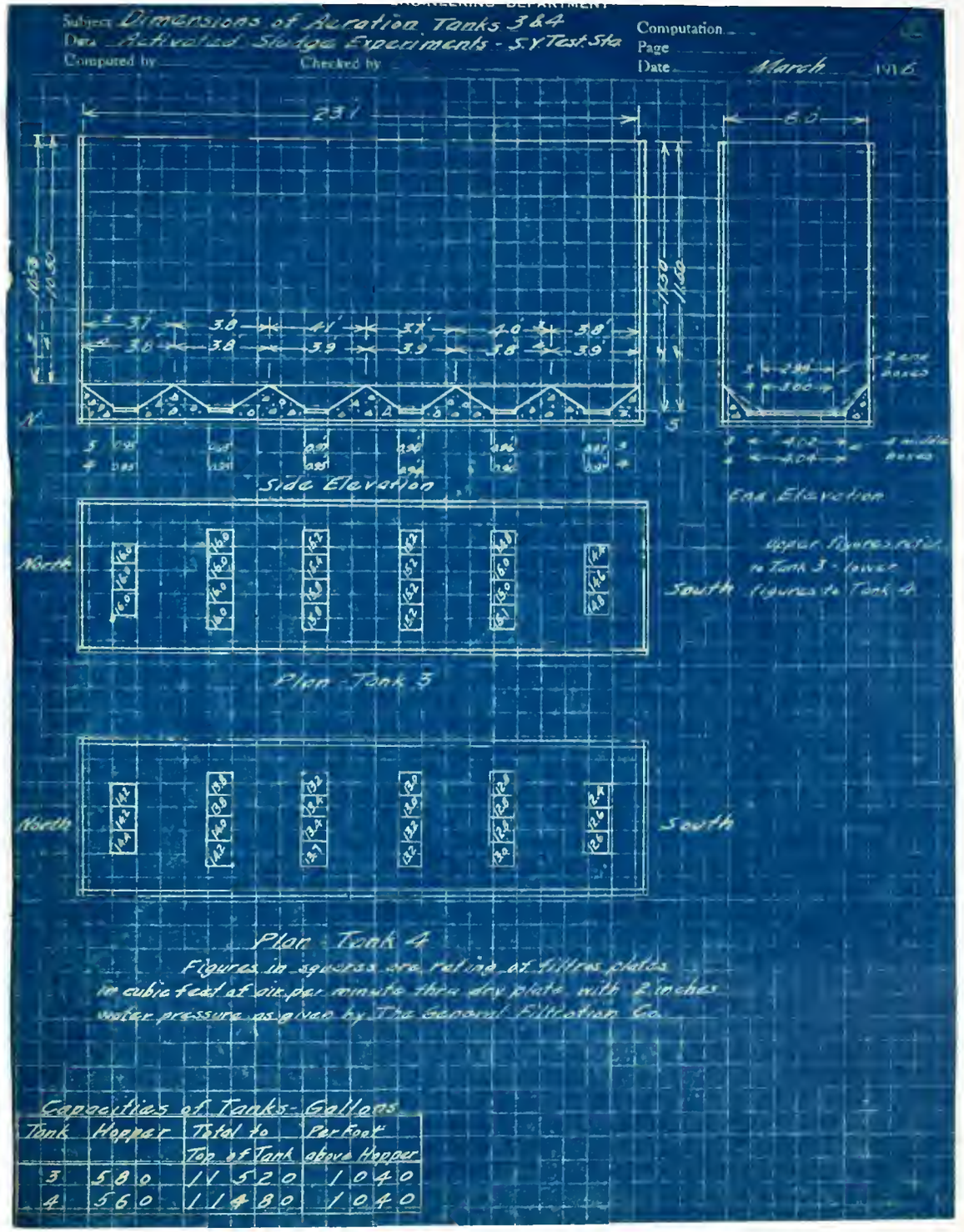


THE SANITARY DISTRICT OF CHICAGO

STOCK YARDS TESTING STATION

Sketch Showing the Arrangement of the Activated Sludge Plant

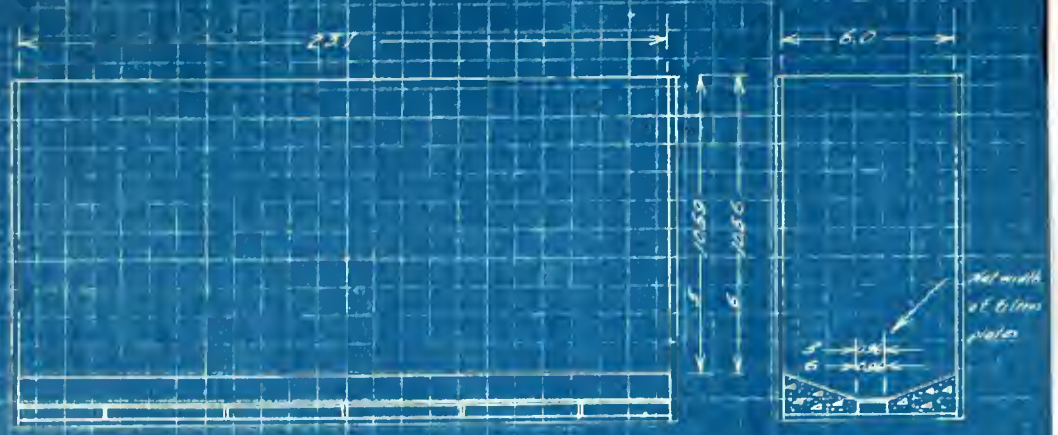
March 1916



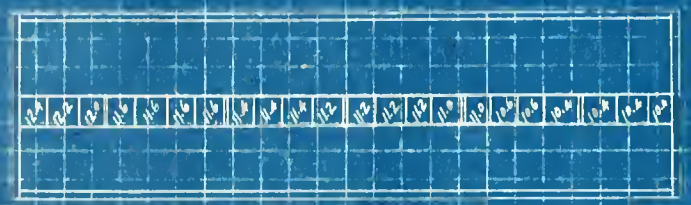
Capacities of Tanks - Gallons

Tank	Hopper	Total to Top of Tank	Per Foot above Hopper
3	580	11520	1040
4	560	11480	1040

Subject: Dimensions of Aeration Tanks 5 & 6
Data: Activated Sludge Experiments - S.K. Test. Sta.
Computed by: ____ Checked by: ____
Computation: ____ Page: 3 Date: March 1916



Side Elevation — End Elevation



Plan of Tank 5

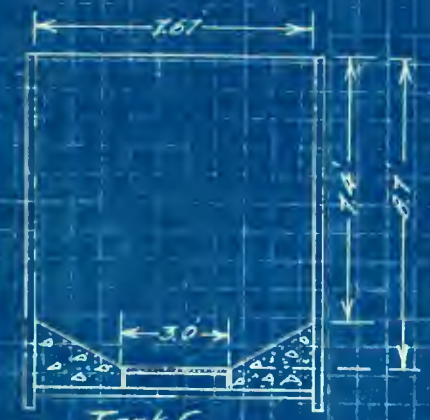
Plan of Tank 6

Figures in squares are the ratings of the filtros plates in cubic feet of free air per minute thru dry plate with 2 inches water pressure, as given by the General Filtration Co.

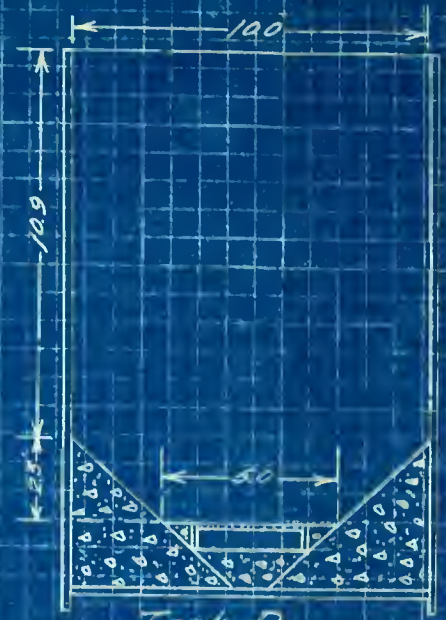
Capacities of Tanks - Gallons

Tank	Hopper	Total to top	Per Foot above Hopper
5	560	11570	1040
6	580	11560	1040

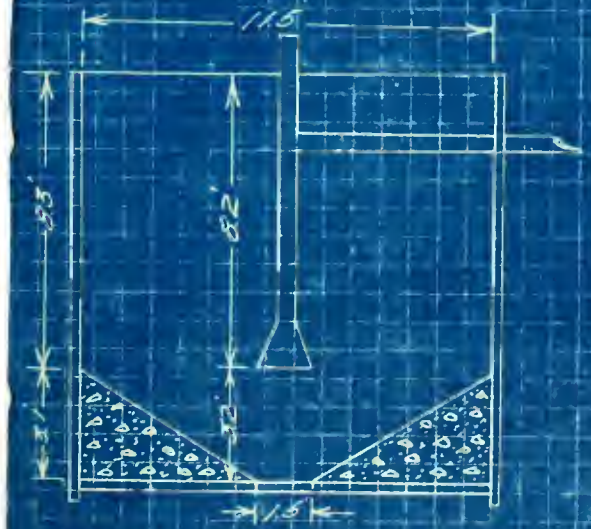
Subject: Dimensions of Tanks C-D-7
Data: Stock Yards Testing Station
Computed by: ____ Checked by: ____
Computation: ____ Page: ____ Date: March 1916



Tank C



Tank D



Tank 7

Tank No.	Capacities in Gallons: Hopper	Per Foot above Hopper	Total to Top of Tank
C	220	350	2780
D	790	590	6740
7	920	780	7390

Subject Activated Sludge
Data Settling Tank D
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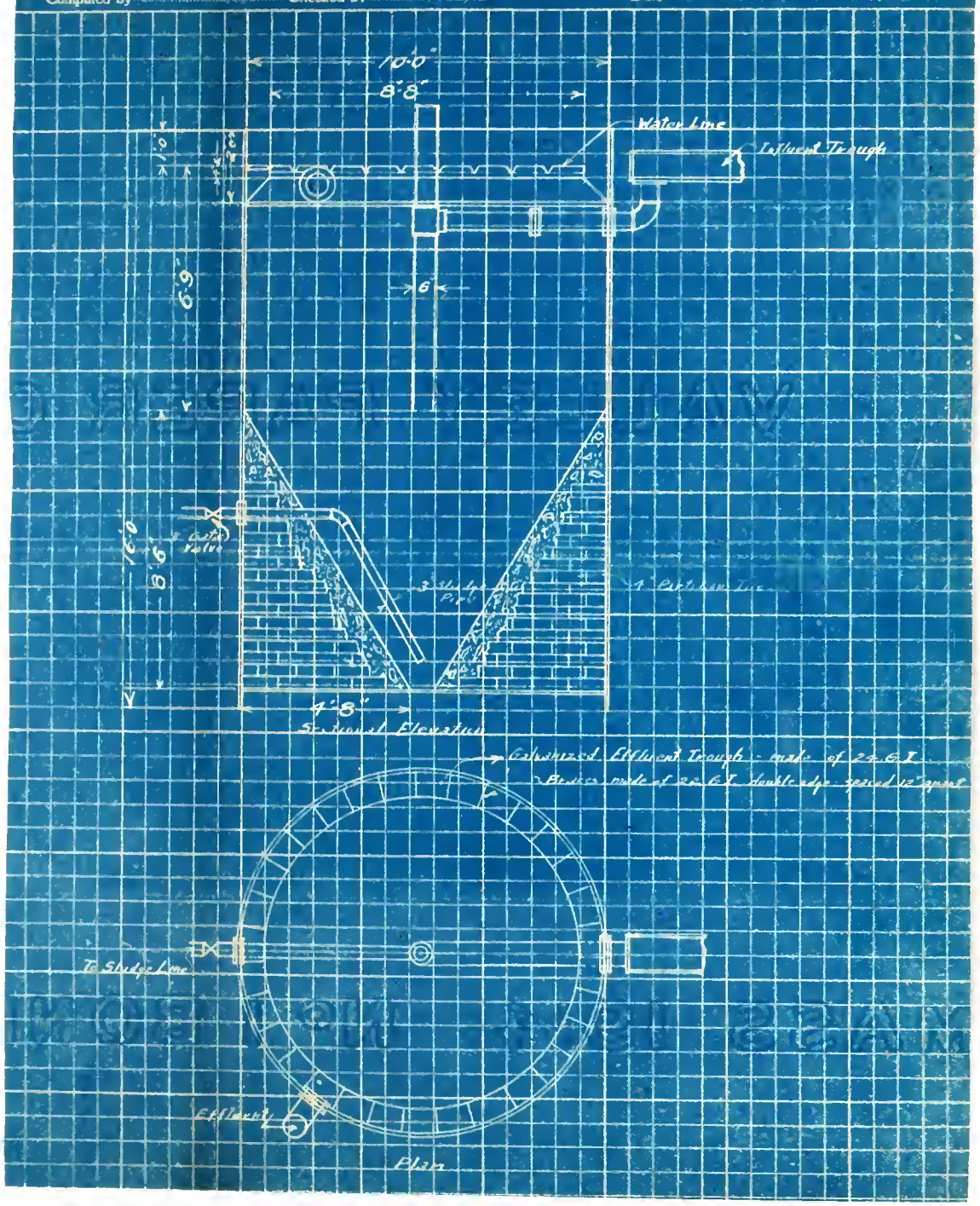
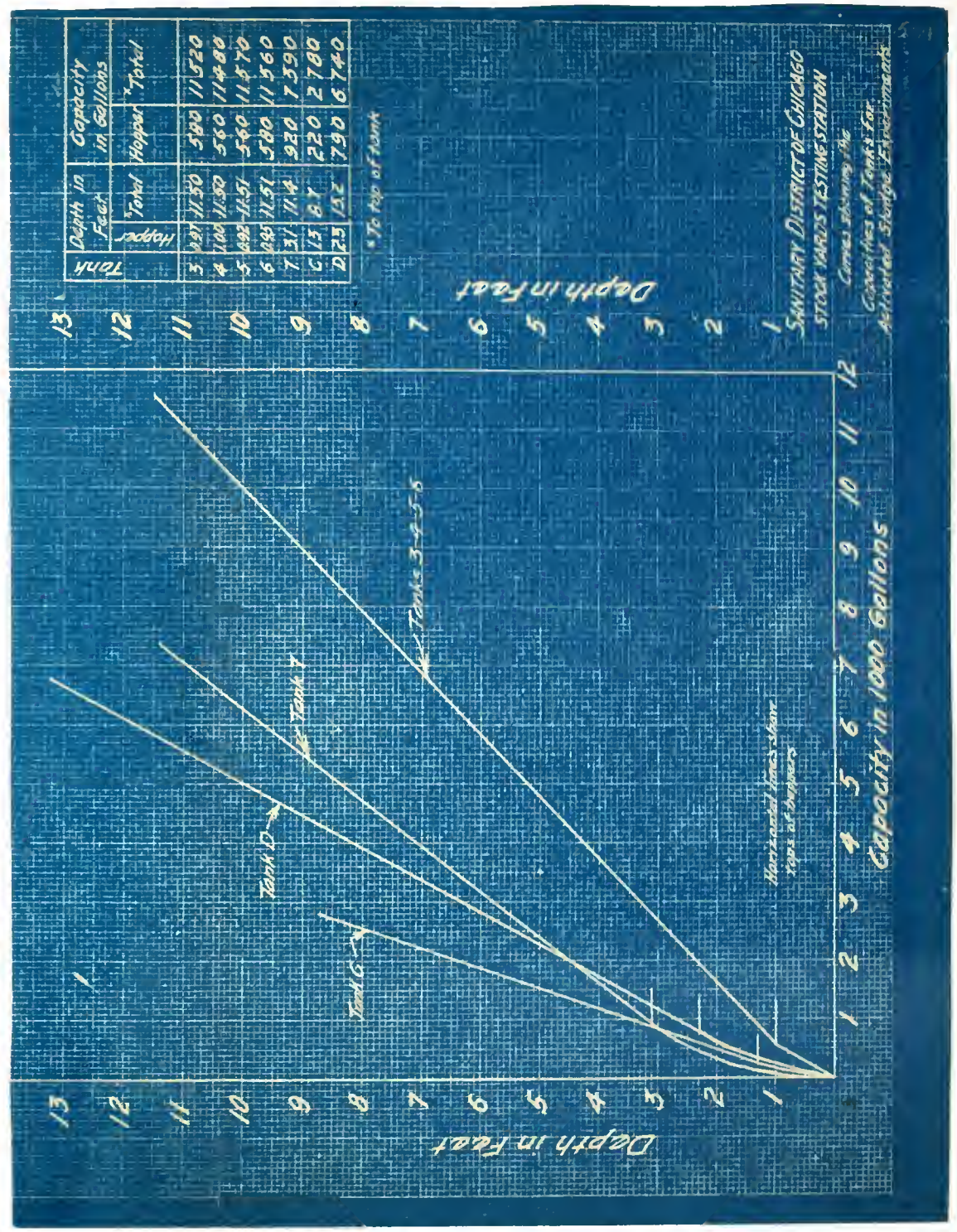
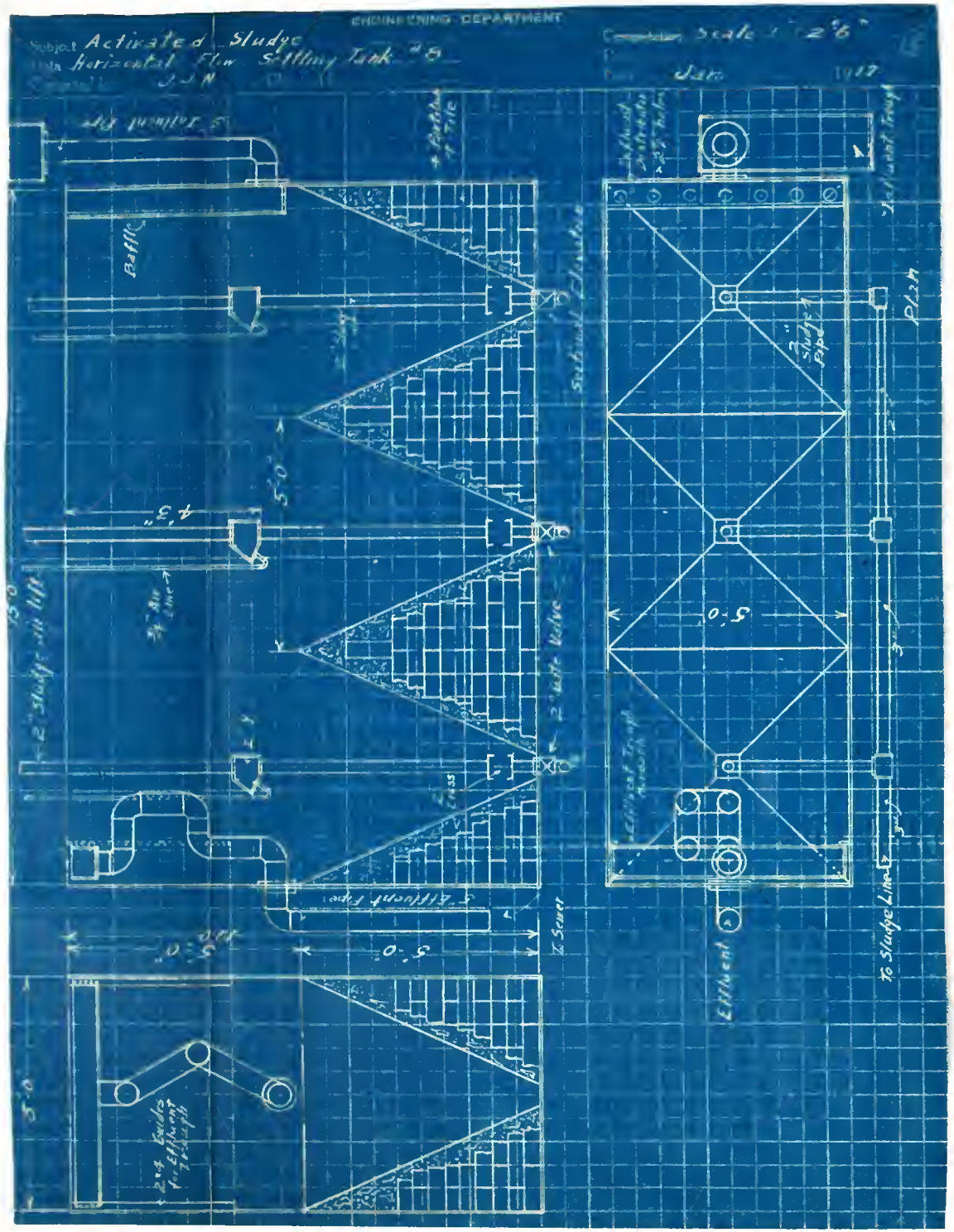
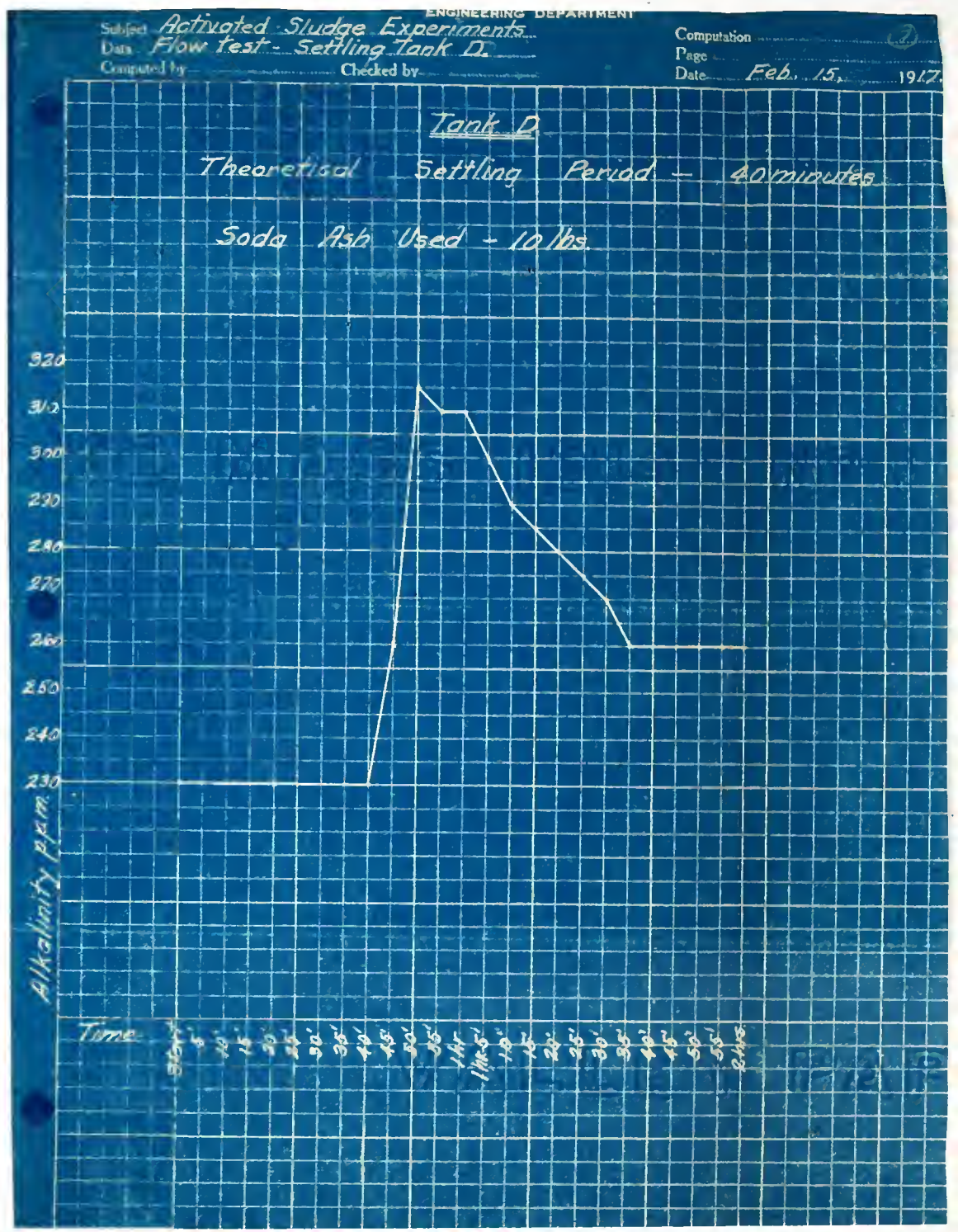




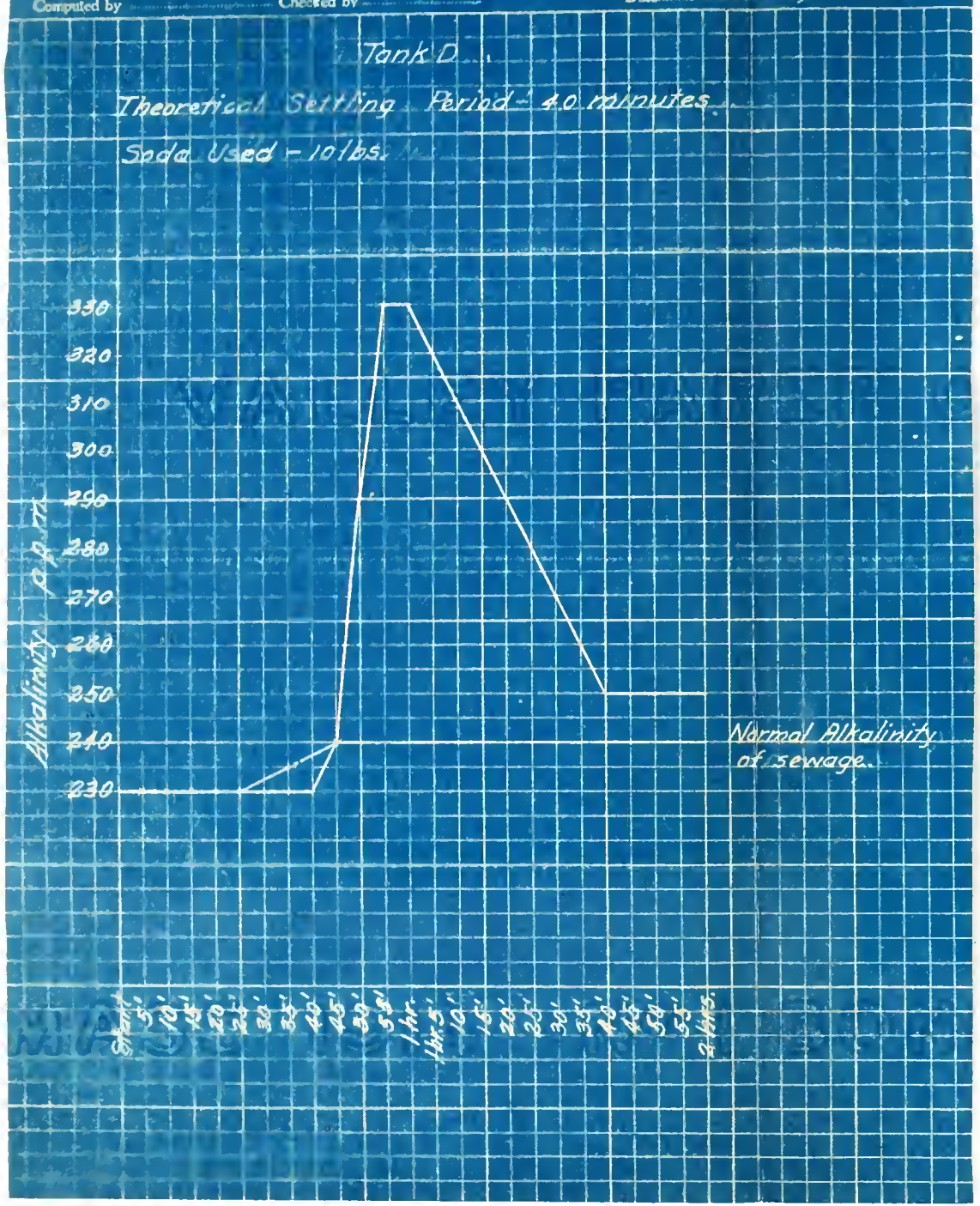
Tank	Depth in Feet		Capacity in Gallons		
	Hopper	Total	Hopper	Total	
3	0.97	11.50	500	11,520	
4	1.00	11.90	560	11,480	
5	0.92	11.51	560	11,570	
6	0.89	11.51	500	11,960	
7	1.31	11.4	920	7,390	
C	1.13	8.7	220	2,780	
D	1.25	13.2	790	6,740	

* To top of tank


ENGINEERING DEPARTMENT
Subject Activated Sludge
Data Horizontal Flow Settling Tank #8
Scale 1" = 2'6"
Jan. 1917
Baffle
Air Lines
Sludge Pipe
Effluent Pipe
To Sewer
Effluent
To Sludge Lines
Plan


ENGINEERING DEPARTMENT
Subject Activated Sludge Experiments
Data Flow Test - Settling Tank D
Computed by
Checked by
Computation
Page
Date Feb. 15, 1917
Tank D
Theoretical Settling Period - 40 minutes
Soda Ash Used - 10 lbs.
Alkalinity P.P.M.
320
310
300
290
280
270
260
250
240
230
Time

Subject: Activated Sludge Experiments
Data: Flow Test - Settling Tank D
Computed by: Checked by:
Computation: 8
Page:
Date: Feb. 26, 1917



Subject:
Data:
Computed by: Checked by:
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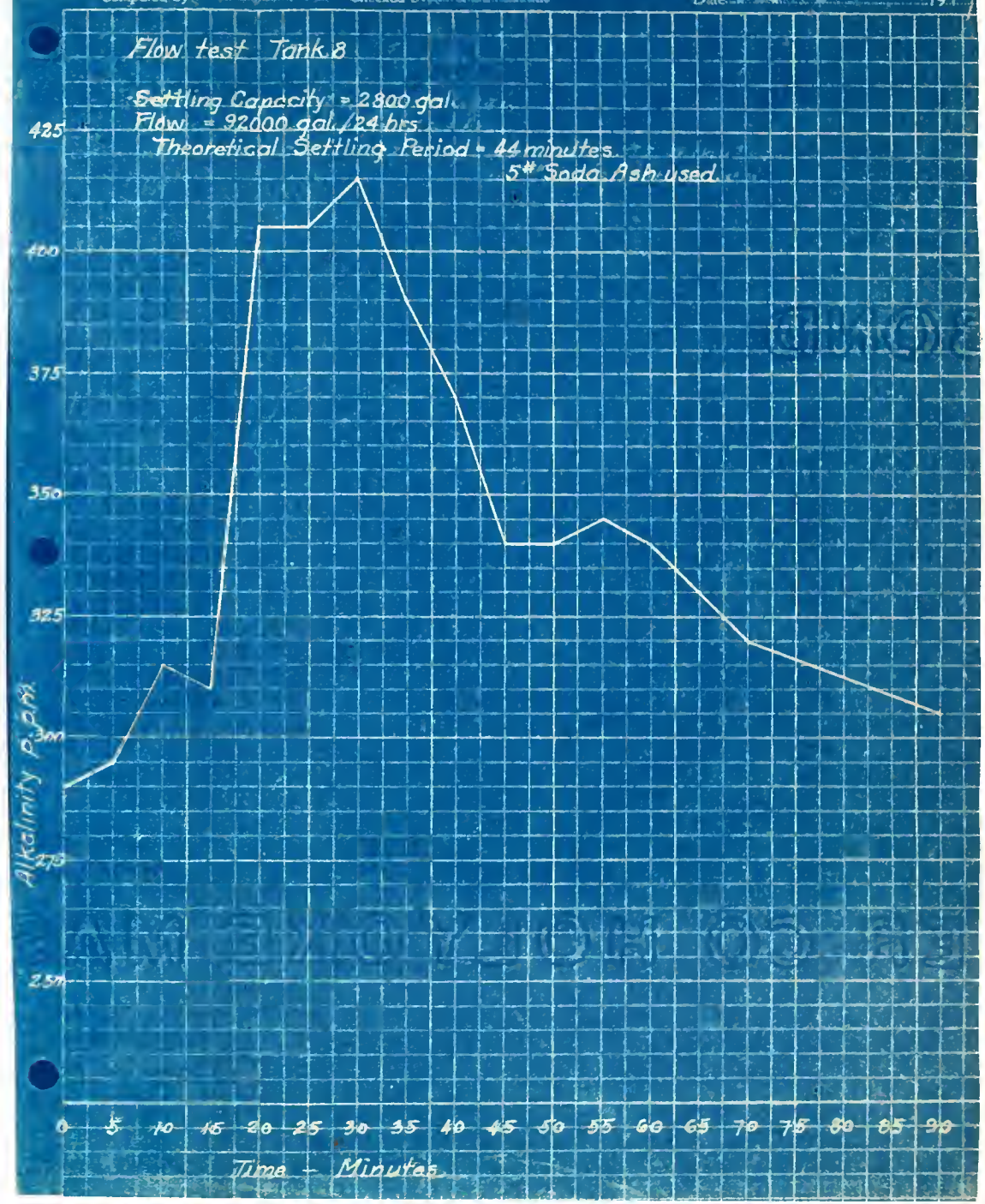
Date: Feb. 10, 1917



Subject: Activated Sludge Expts.
Data:
Computed by: J. J. N. Checked by:
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No of Run	Period	Sewage Treated Gallons per 24 Hrs. Rate	Sewage Treated Gallons per 24 Hrs. Actual	Period in Hours Aeration	Period in Hours Settling	Air Cu. Ft. per Gallon Sewage	Air Cu. Ft. per Sq. Ft. per Min.
1	1916 July 2 to 10	57500	50900	10.2	1.4	3.91	0.25
2	July 11 to 14	52000	50500	13.2	1.7	4.41	0.28
3	July 15 to 26	53500	52960	13.0	1.7	4.22	0.28
4	July 27 to Aug 14	53600	53300	12.3	1.04	3.95	0.26
5	Aug. 15 to 28	79500	76800	9.0	1.0	3.50	0.34
6	Aug. 28 to Sept. 16	72750	67600	8.8	1.0	3.72	0.31
7	Sept. 17 to Oct. 15	72750	67500	9.3	1.06	3.66	0.31
8	Oct. 15 to 23	72750	68700	8.9	0.95	3.27	0.28
9	Oct. 23 to Nov. 24	97000	85000	7.2	0.65	4.17	0.44
10	Nov. 24 to Dec. 8	80250	67300	9.4	0.85	5.63	0.48
11	Dec. 8 to 16	80250	70840	9.3	0.84	6.52	0.59
12	1917 Dec. 16 to Jan. 8	80250	72600	8.5	0.77	4.07	0.38
13	1917 Jan. 8 to Feb. 5	55000	47700	10.9	0.98	3.97	0.24
14	Feb. 5 to Mar. 6	81600	70700	8.1	0.73	3.17	0.28
15	March 6 to 26	48500	42200	6.9	1.17	4.23	0.45

Subject: Activated Sludge Expts.
Data: Chemical Results Summary
Computed by: Checked by:
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No. of Run	Period of Operation 1916	Sample	Influent P.P.M. T.S.M.	Influent P.P.M. Nitrogen as Organic N	Influent P.P.M. Nitrogen as Free Amm.	Effluent Parts Per Million T.S.M.	Effluent Parts Per Million Nitrogen as Organic N	Effluent Parts Per Million Nitrogen as Free NH_3	Effluent Parts Per Million Nitrogen as Nitrites	Effluent Parts Per Million Nitrogen as Nitrates	Effluent Parts Per Million Turbidity	Dissolved Oxygen	B.O.C.	Average Relative Stability Effluent	Average Relative Stability Tank 5	Average Relative Stability Tank 4
1	July 2 to 10	Day	365	42	22	87	9.7	8.2	2.5	4.7	23			70		30
		Night	152	34	15	52	5.5	4.2	2.65	7.1	14			100		52
		Sunday	156	19	13	52	7.1	3.8	0.8	8.6	17			99		87
		Aver.	203	32	17	65	7.7	5.6	2.0	6.7	18			87		51
2	July 11 to 14	Day	449	50	23	113	9.1	11.5	3.37	3.69	23			52	68	
		Night	175	27	16	71	13.0	5.8	5.6	5.9	26			87	90	
		Sunday													94	
		Aver.	335	40	20	96	10.7	9.3	4.3	4.61	27			67	81	
3	July 15 to 26	Day	302	43	19	71	7.8	4.1	5.3	2.8	18			80	73	30
		Night	136	18	12	73	7.2	2.1	5.2	4.6	17			93	90	52
		Sunday	157	25	11	87	12.1	1.5	5.9	4.9	17			97	94	87
		Aver.	220	32	15	75	8.1	2.9	5.6	3.8	18			90	81	51
4	July 27 to Aug. 14	Day	370	48	17	55	7.3	7.2	6.5	2.1	14			90	68	
		Night	168	21	12	90	6.8	5.2	6.5	3.4	13			95	90	
		Sunday	131	28	10	31	5.4	1.7	3.6	5.1	12			100	94	
		Aver.	262	36	14	64	6.9	5.5	2.5	2.9	14			93	81	
5	Aug. 15 to 28	Day	360	45	20	52	7.1	13.7	1.74	6.15	18			28		
		Night	142	23	12	64	8.2	10.3	3.12	4.55	13			69		
		Sunday	176	31	10	50	6.5	9.5	3.6	3.3	20			95		
		Aver.	257	35	16	56	7.4	11.9	2.50	5.17	17			52		
6	Aug. 29 to Sep. 16	Day	380	53	17	18	4.8	7.0	1.75	1.86	13			72	68	
		Night	256	28	12	21	5.7	4.2	1.77	4.06	11			73	90	
		Sunday	155	33	10	14	4.4	2.1	3.6	9.5	12			89	94	
		Aver.	301	41	14	18	5.1	5.2	2.05	3.84	12			75	81	

Subject Activated Sludge Expts. Data Chemical Results Summary Computed by Checked by Computation Page Date 19

No. of Run	Period of Operation	Sample	Influent P.P.M. T.S.M.	Influent P.P.M. Nitrogen as Organic N	Influent P.P.M. Nitrogen as Free Amm.	Effluent Parts Per Million T.S.M.	Effluent Parts Per Million Nitrogen As Organic N	Effluent Parts Per Million Nitrogen As Free NH_3	Effluent Parts Per Million Nitrogen As Nitrites	Effluent Parts Per Million Nitrogen As Nitrates	Effluent Parts Per Million Turbidity	Dissolved Oxygen	B.O.C.	Average Relative Stability Effluent	Average Relative Stability Tank 5	Average Relative Stability Tank 4
7	1916 Sept. 17 to Oct. 14	Day	552	61	23	32	6.9	12.0	1.10	1.55	17			59	44	23
		Night	318	32	13	65	9.3	11.4	1.51	1.70	14			65	75	42
		Sunday	172	21	11	47	11.8	8.0	1.24	3.45	12			92	81	39
		Aver.	410	45	18	46	8.4	11.2	1.26	1.83	15			66	58	31
8	Oct. 15 to 22	Day	490	59	18	46	9.2	18.5	0.23	0.26	20	0.6		36	37	10
		Night	268	34	13	42	8.7	13.9	0.57	1.34	14	1.0		41	34	15
		Sunday	211	25	9	24	7.6	10.8	1.16	5.13	10	1.7		83	44	23
		Aver.	340	42	14	38	8.6	14.8	0.61	2.07	16	1.1		52	37	14
9	Oct. 23 to Nov. 23	Day	532	77	19	31	10.9	29.2	0.10	0.27	22	0.8	62	20	17	
		Night	325	42	13	36	10.8	27.9	0.10	0.40	25	0.7	57	23	16	
		Sunday	389	38	14	22	8.1	27.0	0.27	0.57	16	1.1	25	38	30	
		Aver.	437	53	17	32	10.5	28.5	0.12	0.35	22	0.8	56	23	19	
10	Nov. 24 to Dec. 7	Day	593	84	20	39	17	31.0	0.05	0.18	51	0.3	65	5	4	4
		Night	321	62	16	43	10	29.0	0.07	0.09	45	0.6	47	9	4	4
		Sunday	299	37	15	25	14	26.0	0.11	0.13	40	2.2	49	22	8	5
		Aver.	441	67	17	38	14	29.0	0.08	0.14	47	0.8	56	10	5	4
11	Dec. 8 to 15	Day	477	75	17	63	14	34.0	0.03	0.23	43	0.9	68	21	22	12
		Night	391	61	14	52	11	29.0	0.08	0.13	34	0.3	65	33	33	25
		Sunday	274	12	10	34	10	27.0	0.16	0.08	20	0.1	35	30	52	34
		Aver.	420	62	15	55	13	31.0	0.06	0.18	37	0.8	63	27	30	19
12	Dec. 16 to Jan. 7, 1917	Day	538	98	19	75	24	27.0	0.00	0.22	68	0.1	112	6	6	
		Night	255	40	12	69	18	27.0	0.01	0.13	59	0.8	86	11	8	
		Sunday	247	32	11	40	13	18.0	0.06	0.19	32	1.7	58	26	28	
		Aver.	375	63	15	64	20	25.0	0.02	0.18	56	0.7	90	13	12	

Subject Activated Sludge Expts. Data Chemical Results - Summary Computed by Checked by Computation Page Date 19

No. of Run	Period of Operation	Sample	Influent P.P.M. T.S.M.	Influent P.P.M. Nitrogen as Organic N	Influent P.P.M. Nitrogen as Free Amm.	Effluent Parts Per Million T.S.M.	Effluent Parts Per Million Nitrogen As Organic N	Effluent Parts Per Million Nitrogen As Free NH_3	Effluent Parts Per Million Nitrogen As Nitrites	Effluent Parts Per Million Nitrogen As Nitrates	Effluent Parts Per Million Turbidity	Dissolved Oxygen	B.O.C.	Average Relative Stability Effluent	Average Relative Stability Tank 5	Average Relative Stability Tank 4
13	1917 Jan. 8 to Feb. 4	Day	465	76	16	46	13	25.0	0.01	0.08	26	1.4	42	36	25	
		Night	202	36	11	71	13	24.0	0.01	0.09	30	2.0	45	37	29	
		Sunday	154	10	11	54	12	19.0	0.03	0.04	20	2.6	33	51	51	
		Aver.	326	53	13	56	13	24.0	0.01	0.07	27	1.8	42	38	30	
14	Feb. 5 to Mar. 5	Day	480	72	15	32	13	23.0	0.01	0.13	41	1.1	45	21	15	
		Night	207	31	8	33	13	20.0	0.02	0.06	40	1.3	41	20	18	
		Sunday	104	17	6	20	8	17.0	0.05	0.07	19	5.3	33	38	27	
		Aver.	330	50	11	30	12	21.0	0.02	0.10	38	1.5	40	23	18	
15	Mar. 6 to 26	Day	427	56	15	23	12	18.0	0.03	0.18	46	1.2	40	24		
		Night	173	25	10	22	9	15.0	0.04	0.26	32	1.7	38	30		
		Sunday	165	24	10	15	14	15.0	0.09	0.22	20	2.6	33	51		
		Aver.	295	40	13	22	12	17.0	0.04	0.21	37	1.6	38	31		

ACTIVATED SLUDGE EXPERIMENTS
SUMMARY OF PERCENT REDUCTION AND OPERATING RESULTS.
JULY 2 TO SEPTEMBER 16, 1916.

Period	Sample	Percent Susp. Matter	Reduction Org.N.	Free Amm.	Parts per Million Nitrite	Nitrate	Avg. Rel. Stab.	Period in Hours Aeration	Settling	Air Cu. Ft. per Gal.
July 2 to 10	Day	76.2	76.9	62.8	2.5	4.7	70	10.2	1.4	3.91
	Night	65.8	83.8	72	2.6	7.1	100			
	D. & N.	73.9	79.5	65.8	2.6	5.7	83			
	Sunday	66.7	54.5	70.8	0.8	8.6	96			
July 11 to 14	Day	74.8	71.8	48.6	3.4	3.7	52	13.2	1.7	4.41
	Night	59.5	51.9	63.8	5.6	5.9	87			
	D.&N.	71.3	73.2	53.5	4.3	4.6	67			
July 15 to 26	Day	77	82	78	5.3	2.8	80	13.0	1.7	4.22
	Night	46	75	82	5.2	4.6	93			
	D.&N.	69	78	80	5.3	3.6	86			
	Sunday	45	52	86	5.9	4.9	97			
July 27 to Aug. 14	Day	85	84	58	6.3	2.1	90	12.3	1.0	3.95
	Night	46	68	57	6.5	3.4	95			
	D.&N.	76	81	57	6.4	2.5	92			
	Sunday	76	81	83	7.0	5.1	100			
Aug. 15 to 28	Day	85.6	84.2	31.5	1.7	6.2	28	9.0	1.0	3.50
	Night	56.5	64.3	14.1	3.1	4.6	69			
	D.&N.	79	78.9	27.6	2.3	5.5	45			
	Sunday	71.6	79	5.0	3.6	3.3	95			
Aug. 29 to Sept. 16	Day	95.3	90.9	58.9	1.8	1.9	72	8.8	1.0	3.72
	Night	91.8	79.6	65	1.8	4.1	73			
	D. N.	94.2	87.9	61.4	1.8	2.8	72			
	Sunday	91.	86.7	79	3.6	9.5	89			

Note: Sunday includes Sundays and holidays.
D. & N. means day and night averaged.

Period	Sample	Per cent Reduction			Nitrogen as p.p.m.		Average Relative Stability	Period in Hours		Air Cu. Ft. per Gallon Sewage
		T.S.M.	Nitrogen as Org. N.	Nitrogen as Free NH_3	Nitrites	Nitrates		Aeration	Settling	
Septr. to Oct. 15	Day	94.6	89.8	47.5	1.10	1.55	59			
	Night	73.5	70.3	12.3	1.51	1.70	65			
	D.&N. Aver.	90.0	83.5	37.9	1.27	1.61	62	9.3	1.06	3.66
	Sundays	72.7	43.8	27.3	1.24	3.45	92			
	Comb. Aver.	88.8	81.4	37.8	1.26	1.80	66			
Oct. 15 to Oct. 23	Day	90.7	94.5	- 2.8	0.23	0.26	36			
	Night	84.8	74.3	- 6.9	0.57	1.34	41			
	D.&N. Aver.	89.0	81.7	- 3.7	0.37	0.71	38	8.9	0.95	3.27
	Sundays	88.6	69.7	- 20.0	1.16	5.13	83			
	Comb. Aver.	88.8	79.5	- 5.7	0.61	2.07	52			
Oct. 23 to Nov. 23	Day	94.8	85.8	- 53.7	0.10	0.27	20			
	Night	89.0	74.3	-101.4	0.10	0.40	23			
	D.&N. Aver.	92.8	82.4	- 68.8	0.10	0.32	21	7.2	0.65	4.17
	Sundays	94.3	78.6	- 92.8	0.27	0.57	38			
	Comb. Aver.	92.9	82.2	- 67.7	0.12	0.35	23			
Nov. 24 to Dec. 8	Day	91.8	79.8	- 55.0	0.05	0.18	5			
	Night	86.7	84.0	- 81.3	0.07	0.09	9			
	D.&N. Aver.	91.7	81.4	- 66.7	0.07	0.14	7	9.4	0.85	5.63
	Sundays	91.7	62.2	- 73.4	0.11	0.13	22			
	Comb. Aver.	91.7	79.2	- 70.7	0.08	0.14	10			
Dec. 8 to Dec. 16	Day	87.1	81.4	-100.0	0.03	0.23	21			
	Night	86.3	32.0	-107.0	0.04	0.13	33			
	D.&N. Aver.	87.0	81.4	-100.0	0.05	0.19	26	9.3	0.84	6.52
	Sundays	87.7	16.7	-170.0	0.16	0.09	30			
	Comb. Aver.	87.0	78.1	-106.5	0.06	0.18	27			
Dec. 16 1916 to Jan. 8 1917	Day	85.9	75.6	- 42.1	0.00	0.22	6			
	Night	78.9	55.0	-125.0	0.01	0.13	11			
	D.&N. Aver.	82.7	70.3	- 68.3	0.00	0.18	8	8.5	0.77	4.07
	Sundays	54.2	59.5	- 63.6	0.06	0.19	26			
	Comb. Aver.	83.0	68.3	- 66.7	0.02	0.18	13			
Jan. 8 to Feb. 5	Day	90.3	83.0	- 56.2	0.01	0.03	36			
	Night	64.9	64.0	-118.0	0.01	0.09	37			
	D.&N. Aver.	84.2	78.0	- 78.5	0.01	0.08	36	10.9	0.98	3.97
	Sundays	65.0	36.8	- 72.7	0.03	0.04	51			
	Comb. Aver.	83.0	75.5	- 78.5	0.01	0.07	38			

Period	Sample	Per cent Reduction			Nitrogen as		Average Relative Stability	Period in Hours		Air Cu. Ft. per Gallon Sewage
		T.S.M.	Nitrogen as Org. N.	Nitrogen as Free NH_3	Nitrites	Nitrates		Aeration	Settling	
Feb. 5 to Mar. 5	Day	93.5	82.0	- 53.3	0.01	0.13	21			
	Night	83.5	58.1	-150.0	0.02	0.06	20			
	D.&N. Aver.	91.3	76.3	- 83.3	0.01	0.10	21	5.1	0.73	3.17
	Sundays	80.7	52.6	-183.0	0.05	0.07	33			
	Comb. Aver.	91.0	76.0	- 91.0	0.02	0.10	23			
Mar. 5 to Mar. 26	Day	95.0	78.7	- 20.0	0.03	0.13	24			
	Night	87.4	64.0	- 50.0	0.04	0.26	30			
	D.&N. Aver.	92.8	74.5	- 30.8	0.03	0.21	27	6.9	1.17	4.23
	Sundays	91.0	41.7	- 50.0	0.09	0.22	51			
	Comb. Aver.	92.5	70.0	- 30.8	0.04	0.21	31			

Subject: Activated Sludge Expts.
Data: Sludge
Computed by: J. J. N. Checked by:
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Period	Sewage Treated Gallons	Sludge: Gallons Disposed	Sludge: Equiv. Lbs Dry	Per Mil. Gal Sewage: Dry Pounds	Per Mil. Gal Sewage: Gallons
July 1 - 31 1916	1556700	13775	1723	1100	8900
Aug 1 - 31	2003300	57290	3998	2000	28600
Sept. 1 - 16	1100500	44070	2532	2300	40000
Sept. 17 - Oct. 14	1889650	72970	4207	2220	38600
Oct. 15 - 22	550100	24420	1386	2520	44300
Oct. 23 - Nov. 23	2720900	193420	6913	2540	71000
Nov. 24 - Dec. 7	942050	47420	4238	4500	50400
Dec. 8 - 15	566700	45610	2010	3540	80400
Dec. 16 - Jan. 7 1917	1672250	117940	6557	3920	70500
Jan. 8 - Feb. 4	1335400	60610	2333	1750	45300
Feb. 5 - Mar. 5	2053600	75700	3889	1900	37000
Mar. 5 - 26	799000	48630	1920	2400	60700
Total	17190150	801855	41706	2420	46500

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Period	Sewage Treated Gallons	Total Suspended Matter: Grade (Screened) P.P.M.	Total Suspended Matter: Effluent P.P.M.	Reduction: P.P.M.	Reduction: Total lbs.	Dry Sludge Removed: lbs. per Million Gallons Sewage	Dry Sludge Removed: Total lbs.	Dry Sludge Removed: lbs. per Mil. Gal. Sewage	Remarks
Sept. 17 to Oct. 15	1889650	410	46	364	5730	3030	4207	2220	Screen not Working
Oct. 15 to Oct. 23	550100	340	38	302	1385	2520	1386	2520	Screen Working
Oct. 23 to Nov. 23	2720900	437	32	405	9170	3370	6913	2540	"
Nov. 24 to Dec. 8	942050	441	38	403	3160	3360	4238	4500	"
Dec. 8 to Dec. 16	566700	420	55	365	1720	3040	2010	3540	
Dec. 16 to Jan. 8	1672250	375	64	311	4390	2590	6557	3920	
Jan. 8 to Feb. 5	1335400	326	56	270	3000	2250	2333	1750	
Feb. 5 to March 6	2053600	330	30	300	5020	2500	3889	1900	Screen not Working
March 6 to March 26	799000	295	22	273	1820	2270	1920	2400	Screen Working
Total	12590150				35335	2820	33453	2650	

TABLE

ANALYSES ACTIVATED SLUDGE

Calculated to dry weight

Date 1916	Source Tank	Sp. Gr.	Moisture	Volatile Matter	Fixed Matter	Organic Nitrogen	Ether	Soluble Acidified	Remarks
July									
8	3,4,5&6	1.004	98.8	56.7	43.3	3.68	4.36	5.86	8:45 A.M.
14	6	1.004	98.5	58.3	41.7	4.48			1 P.M.
21	6	1.000	98.3	66.9	33.1	4.00	5.28	7.50	Settled 1 Hr.
28	6	1.000	99.2	57.1	42.9	4.16			
Aug.									
4	6	1.000	98.9	44.6	55.4	3.64	4.92	6.68	Outlet
11	6	1.000	98.9	55.4	44.6	3.52			N. end
18	6	1.000	99.5	55.6	44.4	3.84	5.52	7.00	Outlet
25	7	1.004	99.4	56.4	43.6	3.68			
Sept.									
1	6	1.009	99.4	56.0	44.0	4.72	6.14	8.70	
8	6	1.005	99.0	59.8	40.2	3.52			
15	6	1.005	99.2	57.7	42.3	4.48	5.78	7.78	
Average		1.003	99.0	56.8	43.2	3.96	5.33	7.25	

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Date	Source Tank	Sp. Gr.	Moisture	Fixed Matter	Volatile Matter	Organic Nitrogen	Ether	Soluble Acidified	Remarks
1916 Sept. 22	6	1.009	99.7	34.0	66.0	3.52	4.20	9.24	Screen & Pressure operation
" 23	6	1.005	99.9	40.8	59.2	3.82	3.18	8.00	
Oct. 6	6	1.005	99.4	43.7	56.3	3.68	2.82	6.90	Considerable Straw & Hair Present
" 13	6	1.004	99.1	35.3	64.7	4.00	3.73	8.03	
" 20	6	1.004	98.7	33.3	66.7	3.84	7.02	9.98	
" 27	6	1.004	99.1	35.5	64.5	4.00	5.90	9.10	
Nov. 3	6	1.004	99.6	44.9	55.1	2.88	3.54	6.42	
" 12	6	1.004	99.3	39.0	61.0	4.16	4.60	7.76	
" 17	6	1.004	99.1	33.2	66.8	3.84	7.26	9.86	
" 24	6	1.004	99.23	39.2	60.8	4.16	7.08	10.52	P_2O_5 = 2.67 K_2O = 1.55
Dec. 1	6	1.004	99.11	31.4	68.6	4.64	4.82	8.30	
" 9	6	1.004	99.37	38.3	61.7	4.80	4.28	5.84	
" 15	6	1.004	99.05	30.0	70.0	5.12	7.50	12.12	
" 22	6	1.004	99.55	38.1	61.9	3.68	3.86	9.26	
" 29	6	1.004	99.14	32.2	67.8	5.28	13.90	14.74	P_2O_5 = 2.78 K_2O = 1.21
1917 Jan. 5	6	1.004	99.07	28.1	71.9	5.44	10.36	12.50	
" 19	6	1.004	99.39	32.9	67.1	5.00	7.90	11.18	
" 26	6	1.002	99.67	45.3	54.7	3.63	3.24	9.12	
Feb. 2	6	1.004	99.42	34.4	65.6	4.43	7.14	12.12	
" 9	6	1.004	99.32	29.7	70.3	5.44	6.46	13.38	
" 16	6	1.004	99.42	30.6	69.4	4.16	7.46	15.54	
" 23	6	1.004	99.14	28.1	71.9	4.96	9.50	12.26	
Mar. 2	6	1.004	99.14	26.6	73.4	5.12	9.64	13.94	
" 9	4	1.004	99.29	32.9	67.1	4.16	8.56	11.66	
" 16	4	1.004	99.33	36.5	63.5	3.36	4.54	8.06	
" 23	4	1.004	99.08	38.4	61.6	3.04	4.08	6.64	
Total	Sept. 15, 1916 Mar. 26, 1917			912.4	1667.6	110.36	63.67	262.62	
Average		1.004	99.22	35.1	64.9	4.27	6.30	10.10	
Average	July 1 to Sept. 15, 1916	1.003	99.0	43.2	56.8	3.96	5.33	7.25	
Average	July 1, 1916 to Mar. 26, 1917	1.004	99.15	37.4	62.6	4.17	6.00	9.25	

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Period	Total Gallons Sewage	Total Gallons Wash Water	Per cent Wash Water	Moist Screenings % Moisture	Dry Screenings Lbs. per Mil. Gal.
1916 July 1 to 31	762300	94900	12.4	78.8	230
Aug. 1 to 31	1 004900	128400	12.7	79.7	516
Sept 1 to 16	496700	78800	15.8	80.8	620
Oct. 15 to 23	227900	37660	16.5	80.2	777
Oct. 23 to Nov. 24	1205900	127470	10.5	81.8	977
1917 Nov. 24 to Jan. 8	1358400	164400	12.1	83.3	1280
1917 Jan. 8 to Feb. 4	627400	134700	21.5	81.6	1200
Feb. 5 to Mar. 5	618800	111800	18.0	80.8	785
Mar. 5 to 26	392200	113800	29.0	79.6	1260
Total	6,634,500	991930	14.8	80.7	570

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Date	Moisture	Calculated to dry weight: Fixed Matter	Volatile Matter	Organic Nitrogen	Ether Soluble	Acidified Soluble	Remarks
Oct. 1916 16-21	56	59	34.1	2.08	6.55	3.54	P_2O_5 = 0.45 ; K_2O = 0.28
23-28	66	62	33.8	1.92	6.04	7.45	
28-30, Nov. 4	68	54	34.5	2.56	7.72	7.94	
Nov. 6-11	61	37	35.1	2.08	6.15	5.82	
13-18	73	37	33.3	2.24	5.02	1.64	
20-25	68	44	35.6	2.40	5.07	1.18	P_2O_5 = 0.30 ; K_2O = 0.35
27-Dec. 2	76	47	35.3	1.76	6.66	1.10	
4-9	80	50	35.0	2.08	5.44	1.58	
11-16	53	58	35.4	2.56	5.03	1.93	
18-23	35	50	35.9	2.72	7.02	1.80	
24-30	26	39	36.1	2.08	6.54	3.30	
1917 Jan. 2-6	84	26	37.3				
Total	719	571	1142.9	262.4	712.4	112.60	
Average	59	4.7	35.3	2.18	5.93	3.33	

Activated Sludge Expts.
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Operation Results – (Day, Nights, Sunday & Holiday Average)

No. of Run	Period of Operation	No. of Days	Temperature Degrees F. Atmos	Temperature Degrees F. Comp. Air	Temperature Degrees F. Inf.	Temperature Degrees F. Eff.	Sewage Treated Gal./Day	Ratio of Flows Sludge/Sewage	Period in Hours Aeration	Period in Hours Settling	Free Air Used cu. Ft. per Sq. Ft. per Minute	Free Air Used cu. Ft. per Gallon Sewage
1	1910 July 2-10	9	71	99			50900	0.76	10.2	1.4	0.25	3.91
2	July 11-14	4	78	110			50500	0.50	13.2	1.7	0.28	4.41
3	July 15-26	12	30	111			52960	0.48	13.0	1.7	0.28	4.22
4	July 27-Aug 4	19	81	104			53300	0.48	12.3	1.04	0.26	3.95
5	Aug 15-28	14	76	108			76900	0.48	9.0	1.0	0.34	3.50
6	Aug 29-Sept 16	19	70	100			67600	0.70	8.8	1.0	0.31	3.72
7	Sept 17-Oct 14	28	60	94			67500	0.69	9.3	1.06	0.31	3.66
8	Oct 15-22	8	49	82		64	68700	0.65	8.9	0.95	0.28	3.27
9	Oct 23-Nov 23	32	46	95		70	85000	0.67	7.2	0.65	0.44	4.17
10	Nov 24-Dec 7	14	44	92		64	67300	0.49	9.4	0.85	0.48	5.63
11	Dec 8-15	8	23	84		60	70840	0.54	9.3	0.84	0.59	6.52
12	1911 Dec 16-Jan 7	23		70		58	72600	0.66	8.5	0.77	0.38	4.07
13	Jan 8-Feb 4	28		60		55	47700	0.93	10.9	0.98	0.24	3.97
14	Feb 5-Mar 5	29		73		56	70700	0.79	8.1	0.73	0.28	3.17
15	Mar 6-Mar 26	18		77		55	42200	0.67	6.9	1.17	0.45	4.23

Activated Sludge Expts.
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Analytical Data

No. of Run	Total Suspended Matter Inf.	Total Suspended Matter Eff.	Total Suspended Matter % Reduction	Nitrogen As Organic Inf.	Nitrogen As Organic Eff.	Nitrogen As Organic % Reduction	Nitrogen As Free Ammonia Inf.	Nitrogen As Free Ammonia Eff.	Nitrogen As Free Ammonia % Reduction	Nitrites	Nitrates	Dissolved Oxygen	B.O.C.	Turbidity	Average Relative Stability Eff.	Average Relative Stability Tank 5	Average Relative Stability Tank 4
1	203	65	68.0	32	7.7	76.0	17	5.6	67.0	2.0	6.7			18	87		
2	335	96	71.3	40	10.7	73.2	20	9.3	53.5	4.3	4.61			27	67		
3	220	75	66.0	32	8.1	74.7	15	2.9	80.8	5.6	3.8			18	90		
4	262	64	76.0	36	6.9	81.0	14	5.7	59.3	6.5	2.9			14	93		
5	257	56	78.0	35	7.4	78.9	16	11.9	25.6	2.5	5.17			17	52		
6	301	18	94.0	41	5.1	87.6	14	5.2	63.0	2.05	3.84			12	75	81	51
7	410	46	88.8	45	8.4	81.4	18	11.2	37.8	1.26	1.89			15	66	58	31
8	340	38	88.8	42	8.6	79.5	14	14.8	-5.7	0.61	2.07	1.1		16	52	37	14
9	437	32	92.9	53	10.5	82.2	17	28.5	-67.7	0.12	0.35	0.8	56	22	23	19	
10	441	38	91.7	67	14.0	79.2	17	29.0	-70.7	0.08	0.14	0.8	56	47	10	5	4
11	420	55	87.0	62	13.0	79.1	15	31.0	-106.5	0.06	0.18	0.8	63	37	27	30	19
12	375	64	83.0	63	20.0	68.3	15	25.0	-66.7	0.02	0.18	0.7	90	56	13	12	
13	326	56	83.0	53	13.0	75.5	13	24.0	-78.5	0.01	0.07	1.8	42	27	38	30	
14	336	30	91.0	50	12.0	76.0	11	21.0	-91.0	0.02	0.10	1.5	40	38	23	15	
15	295	22	92.5	40	12.0	70.0	15	17.0	-308	0.04	0.21	1.6	38	37	31		